NASA Technical Memorandum TM 103816

Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-35

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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-35

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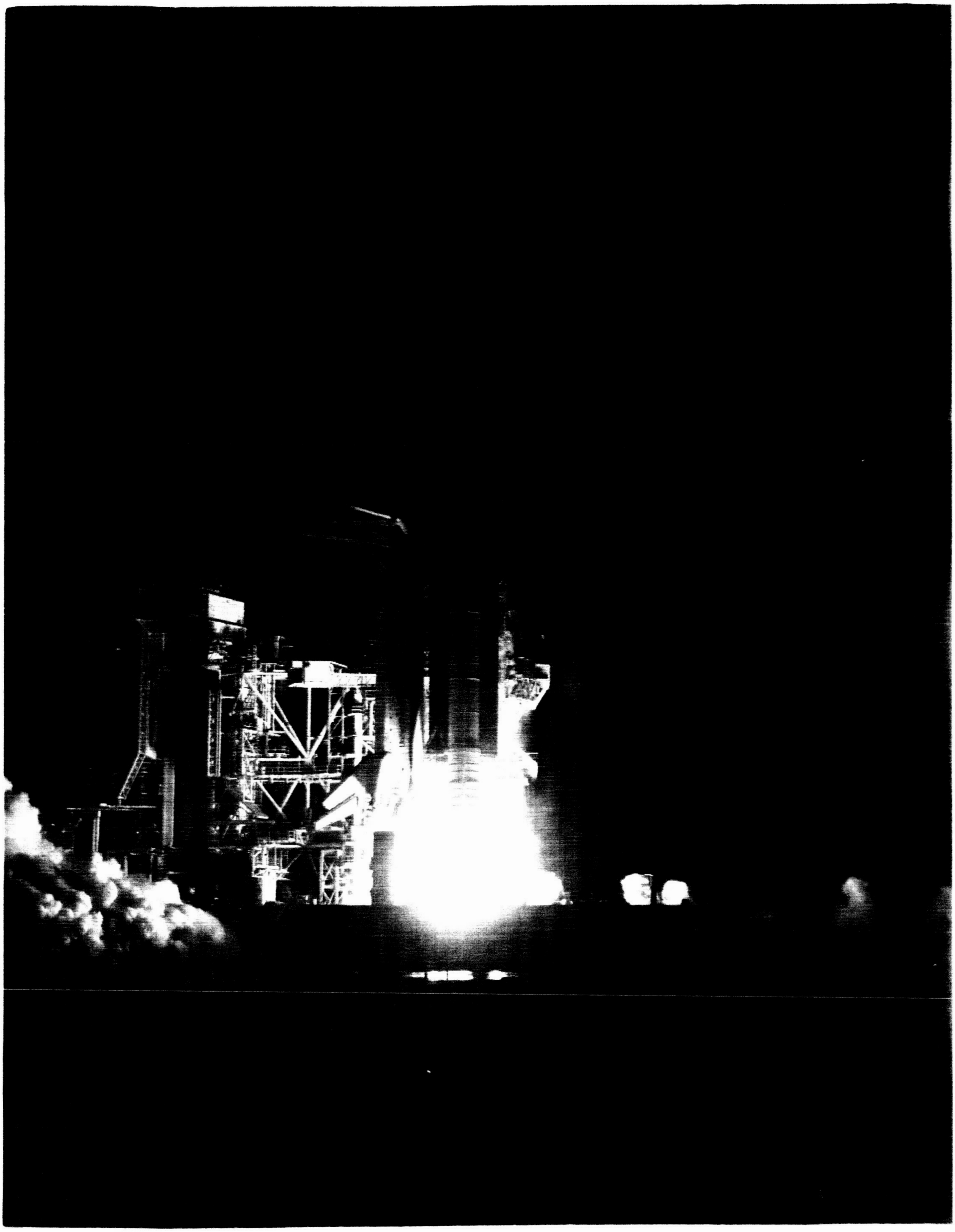
FOREWORD

The Debris Team is continuing its effort to develop and implement measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine processing and operations.



Shuttle mission STS-35 was launched at 1:49 a.m. EST 12/2/90

1.0 Summary

The first launch attempt of STS-35 was scrubbed on 29 May 1990 due to high concentrations of hydrogen in the Orbiter aft compartment and in the LH2 TSM. Hydrogen leak detectors LD54 and LD55, which had been positioned above the LH2 umbilical by the Ice Team, read as high as 45,000 ppm at one point. A special, limited tanking test of the LH2 tank was conducted on 6 June 1990 in an effort to obtain more data on the LH2 leak in the area of the LH2 ET/ORB umbilical 17-inch feedline disconnect. The high concentrations of hydrogen reappeared in this area when liquid hydrogen flowed through the 17-inch line. On-pad repairs were not successful and the SSV stack was rolled back to the VAB on 12 June 1990. The Orbiter was demated and the ET/ORB LH2 umbilical hardware, which had leaked on the first launch attempt, had been changed with the installation of OV-105 LH2 umbilical and a 6000 series replacement umbilical on ET-35. The second and third launch attempts of STS-35 were scrubbed on 5 September and 17 September 1990 due to continued high concentrations of hydrogen in the Orbiter aft compartment. Although on-pad repairs were attempted, the SSV stack was rolled back to the VAB on 8 October 1990 because of a hurricane threat. After replacing seals and tightening flanges in the aft compartment, the SSV was rolled out to pad 39B and a tanking test was performed on 30 October 1990. Additional test fixtures, sensors, baggies, and cameras had been installed in the aft compartment to aid in detecting possible hydrogen leaks. Leak detectors LD54 and LD55 were also utilized. The tanking test was successful with no significant hydrogen leakage detected.

Debris and Photo Analysis Team activities for Mission STS-35 began with the pre-launch debris inspection of the launch pad and Shuttle vehicle on 30 November, 1990. No major anomalies were observed on OV-102 (Columbia), BI038, or ET-35. Minor facility discrepancies were corrected prior to cryoloading the vehicle.

The vehicle was cryoloaded for flight on 1 December 1990. No LCC/OMRS violations were detected during the Ice Inspection, but one IPR on a 24-30 inch intertank TPS crack was taken. The crack was 1/4-inch wide, exhibited no offset, and was not filled with ice or frost. The condition was accepted for launch by MRB approval. Similar cracks in this location have occurred previously on STS-6 (LWT 1) and STS-29R (LWT 29). Martin Marietta is investigating the potential for unusual structural stresses induced by the cryoloading sequence of the tank. Due to facility LO2 pump problems, the LH2 tank was almost completely filled before LO2 tank loading began. There were no other ET anomalies. Light condensate, but no ice or frost, was present on the acreage areas of the External Tank. Nine Ice/Frost console observation anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. The LH2 umbilical leak sensor detected no significant hydrogen during

the cryo load. The tubing was successfully removed from the vehicle with no TPS contact or damage. At launch, the ET ice condition was well within the data base for ice formation.

A debris inspection of Pad 39B was performed after launch. No significant flight hardware or TPS material was found with the exception of one Q-felt plug from the Orbiter base heat shield. Launch damage to the holddown posts was minimal, though the EPON shim material on all south holddown posts was debonded to some degree. Shim material was missing from the shoe sidewalls on HDP #5 and later found attached to the LH SRB aft skirt foot. No signs indicative of stud hang-up were visible. No fragments from HDP debris containers were found. The GH2 vent line had latched properly. Two facility cable tray covers were found and several others on the structure were loose. The modification program to replace old cable tray cover fasteners with new trapeze fasteners is still in work at Pad 39B.

A total of 127 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the success of the mission. SSME ignition vibration/acoustics caused the loss of small pieces of tile surface coating material from tiles on the upper surface of the elevons, base heatshield, OMS nozzle base, body flap, and LH RCS stinger. Three NSI cartridge fragments fell from HDP #1 aft skirt stud hole (E-9), four ordnance fragments fell from the HDP #2 stud hole (E-8), and one fragment fell from the HDP #8 stud hole (E-14, 28) shortly after liftoff. Light-colored particles fell out of the SRB plume just after the roll maneuver and later in flight. Similar particles on previous flights have been attributed to either chunks of SRB propellant/inhibitor or pieces of aft skirt instafoam. A 360-inch camera lens was substituted for the usual 180-inch lens on film item E-207 for this mission to obtain data on SRB thermal curtain performance. This change provided an excellent close-in view of the aft end of the vehicle by doubling the size of the image. A piece of thermal curtain tape came loose near the nozzle extension, fluttered in the air flow near the aft ring, and was drawn into the SRB plume. This piece of tape was significantly different in appearance and behavior than the thermal curtain material observed on STS-38.

On-orbit photography of the External Tank after separation from the Orbiter revealed at least 12 divots on the LH2 tank-to-intertank +Z (Orbiter) side flange closeout and one divot on the upper LH2 tank acreage near the LH bipod closeout. Six of the divots had a major dimension of 8-10 inches. No other anomalies were visible on the ET. Orbiter performance, landing gear extension, wheel touchdown and vehicle rollout after landing was nominal.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums exhibited no missing TPS, but a total of 51 debonds over fasteners. The frustum severance rings, utilizing the new pin retainer clips, were missing no pins. HDP #1, 3, and 5 DCS plungers were obstructed from seating properly by frangible nut halves. Ordnance fragments also prevented the HDP #6 DCS plunger from seating. Post flight disassembly of the Debris Containment System revealed 5 of 8 DCS's had retained less than 90 percent of the ordnance debris. A 10"x2" piece of EPON shim material was missing from HDP #4 aft skirt foot prior to water impact. Two pieces of EPON shim sidewall material (10"x1" and 6"x1/2"), which should have remained bonded to the HDP #5 shoe, were found attached to the sides of the aft skirt foot after retrieval.

A post landing inspection of OV-102 was performed at EAFB on Runway 22. The Orbiter TPS sustained a total of 147 hits, of which 17 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 132 hits, of which 15 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the number of hits on the lower surface was average. Also, based on the severity of damage as indicated by surface area and depth, this flight was average. The plunger in the EO-3 (LO2) separation fitting ordnance debris container was obstructed by a booster cartridge and failed to seat properly. Obstruction of these plungers by ordnance debris occurs frequently. The EO-1 and EO-2 fitting separation devices appeared to have functioned properly, though the RH stop bolt on the EO-1 assembly was bent.

Streaks/deposits were present on both wing leading edge RCC panels. Lab analysis revealed the streaks were caused by TPS materials, SRB separation products, and landing site products. The lower surface tile samples indicated localized heating from re-entry, but the only materials recovered from the damage sites were tile TPS elements.

A total of 9 Post Launch Anomalies were observed during this mission assessment.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

Team Composition:	NASA KSC, NASA MSFC, NASA JSC, LSOC SPC, RI - DOWNEY, MMMSS - MAF, USBI - BPC, MTI - UTAH

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective:	Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.
Areas:	MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle external surfaces
Time:	L - 1 day
Requirements:	OMRSD S00U00.030 - An engineering debris inspection team shall inspect the Shuttle and launch pad to identify and resolve potential debris sources. The prelaunch vehicle and pad configuration shall be documented and photographed.
Documents:	OMI S6444
Report:	Generate PR's and recommend corrective actions to pad managers.

2) Launch Countdown Firing Room 2

Objective:	Evaluate ice/frost accumulation on the Shuttle and/or any observed debris utilizing OTV cameras.
Areas:	MLP deck, FSS, Shuttle external surfaces
Time:	T - 6 hours to Launch + 1 hour or propellant drainback
Requirements:	OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization.
Documents:	OMI S0007, OMI S6444
Report:	OIS call to NTD, Launch Director, and Shuttle managers. Generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective:	Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.
Areas:	MLP deck, FSS, Shuttle external surfaces
Time:	T - 3 hours (during 2 hour BIH)
Requirements:	OMRSD S00U00.020 - An engineering debris inspection team shall inspect the Shuttle for ice/frost, TPS, and debris anomalies after cryo propellant loading. Evaluate, document, and photograph all anomalies. During the walkdown, inspect Orbiter aft engine compartment (externally) for water condensation and/or ice formation in or between aft compartment tiles. An IR scan is required during the Shuttle inspection to verify ET surface temperatures. During the walkdown inspect ET TPS areas which cannot be observed by the OTV system.
Documents:	OMI S0007, OMI S6444
Report:	Briefing to NTD, Launch Director, Shuttle management; generate IPR's.

4) Post Launch Pad Debris Inspection

Objectives:	Locate and identify debris that could have damaged the Shuttle during launch
Areas:	MLP zero level, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to the perimeter fence, walkdown of the beach from Playalinda to Complex 40, aerial overview of inaccessible areas.
Time:	Launch + 1 hours (after pad safing, before washdown)
Requirements:	OMRSD S00U00.010 - An engineering debris inspection team shall perform a post launch pad/area inspection to identify any lost flight or ground systems hardware and resultant debris sources. The post launch pad and area configuration shall be documented and photographed.
Documents:	OMI S0007, OMI S6444

Report: Initial report to NTD and verbal briefing to Level II at L+8 hours; generate PR's.

5) Launch Data Review

Objective: Detailed review of high speed films video tapes, and photographs from pad cameras, range trackers, aircraft and vehicle onboard cameras to determine possible launch damage to the flight vehicle. Identify debris and debris sources.

Time: Launch + 1 day to Launch + 6 days

Requirements: OMRSD S00U00.011 - An engineering film review and analysis shall be performed on all engineering launch film as soon as possible to identify any debris damage to the Shuttle. Identify flight flight vehicle or ground system damage that could affect orbiter flight operations or future SSV launches.

Documents: OMI S6444

Report: Daily reports to Level II Mission Management Team starting on L+1 day through landing; generate PR's.

6) SRB Post Flight/Retrieval Inspection

Objective: Evaluate potential SRB debris sources. Data will be correlated with observed Orbiter post landing TPS damage.

Areas: SRB external surfaces (Hangar AF, CCAFS)

Time: Launch + 24 hours (after on-dock, before hydrolasing)

Requirements: OMRSD S00U00.013 - An engineering debris damage inspection team shall perform a post retrieval inspection of the SRB's to identify any damage caused by launch debris. Anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Documents: OMI B8001

Report: Daily reports to Level II Mission Management Team. Preliminary report to SRB Disassembly Evaluation Team. Generate PR's.

7) Orbiter Post Landing Debris Damage Assessment

Objective:	Identify and evaluate areas of Orbiter TPS damage due to debris and correlate if possible, source and time of occurrence. Additionally, runways are inspected for debris/sources of debris
Areas:	Orbiter TPS surfaces, runways
Time:	After vehicle safing on runway, before towing
Requirements:	OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected by the Team shall be documented and photographed; the proper management authority shall be notified and corrective actions taken.
Requirements:	OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but was not present or was not identified during pre-launch runway inspection. Obtain photographic documentation of any debris, debris sources, or flight hardware that may have been lost on landing.
Requirements:	OMRSD S00U00.060 - An engineering debris inspection team shall map, document, and photograph debris-related Orbiter TPS damage and debris sources.
Requirements:	OMRSD S00U00.012 - An engineering debris damage inspection team shall perform a post landing inspection of the orbiter vehicle to identify any damage caused by launch debris. Any anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.
Requirements:	OMRSD V09AJ0.095 - An engineering debris inspection team shall perform temperature measurements of RCC nose cap and RCC RH wing leading edge panels 9 and 17.
Documents:	OMI S0026, OMI S0027, OMI S0028

Report: Briefing to NASA Convoy Commander and generate PR's. Preliminary report to Level II on the day of landing followed by a more detailed update the next day.

8) Level II report

Objective: Compile and correlate data from all inspections and analyses. Results of the debris assessment, along with recommendations for corrective actions, are presented directly to Level II via SIR and PRCB. Paper copy of complete report follows in 3 to 4 weeks. (Ref NASA Technical Memorandum series).

3.0 HYDROGEN LEAK

3.1 FIRST LAUNCH ATTEMPT SCRUB

The STS-35 launch was scrubbed due to high concentrations of hydrogen in the Orbiter aft compartment and in the LH2 TSM. Hydrogen leak detectors LD54 and LD55, which had been positioned above the LH2 umbilical by the Ice Team, read as high as 45,000 ppm at one point. The LO2 tank had been filled to 25 percent and the LH2 tank 20-30 percent. A post-drain inspection of ET-35 was performed at Pad 39A from 0800-0930 hours on 30 May 1990.

The tumble valve cover exhibited no anomalies. There was no TPS damage to the ET nosecone, footprint area, grid, or fairing. However, thousands of winged insects rested on the nosecone and ogive TPS.

No TPS damage, such as divots or cracks on the tank acreage, were visible.

Ice had accumulated in both LH and RH SRB cable tray to upper strut fairing interfaces. There were no anomalies with the +Y and -Y flow restrictors. Ice approximately 1-inch thick still covered EB-7 and EB-8.

The hydrogen detection system butcher paper was intact. The GH2 detection system tygon tubing was in the proper position.

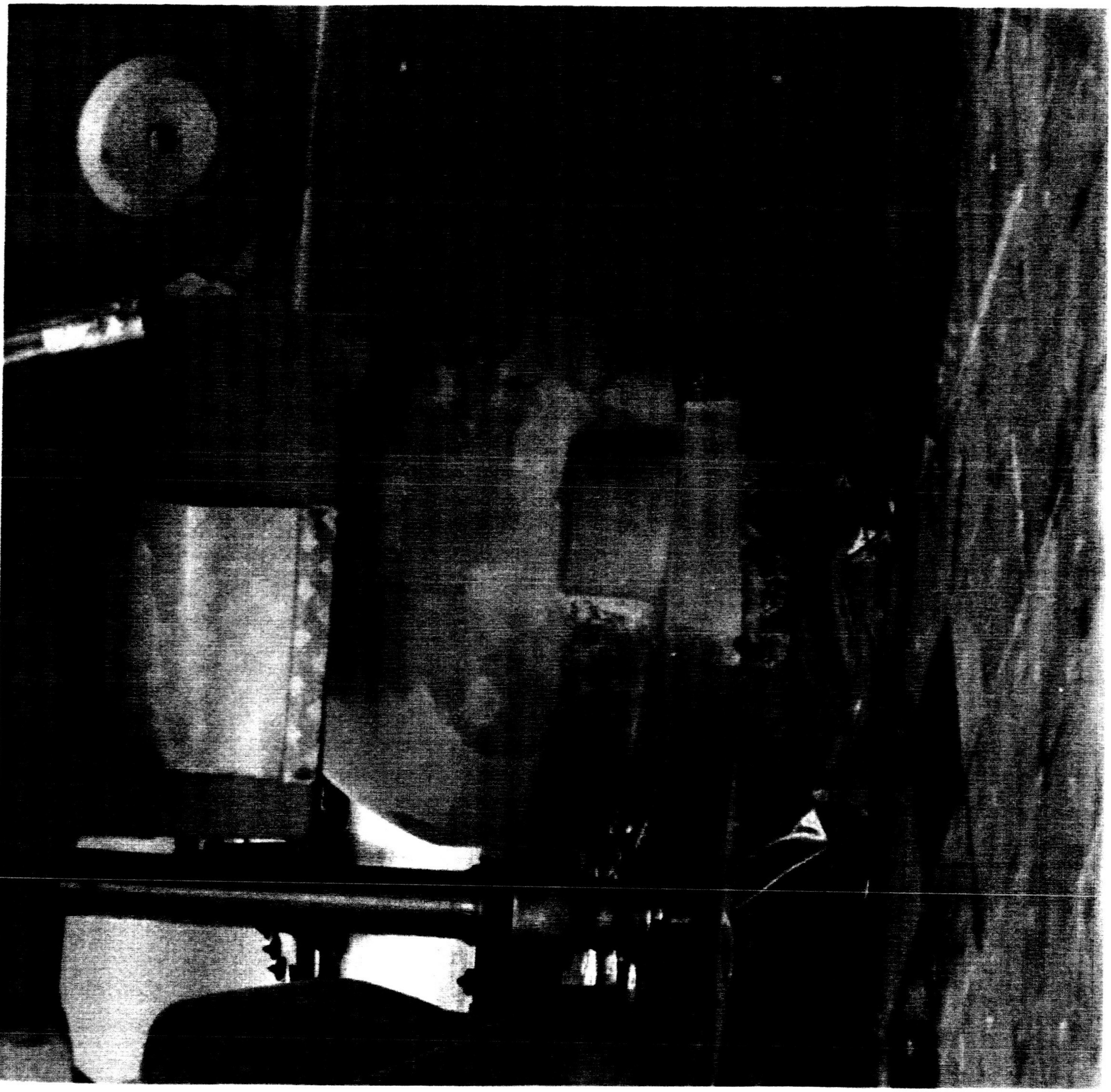
Visually, there were no anomalies on the ET/ORB LH2 umbilical. No ice was present in the LH2 feedline bellows and LH2 recirculation line bellows. Solid ice (4 inches long) was attached to the LH2 umbilical forward outboard purge vent. IPR 35RV-208 had documented a stream of cryo-pumped liquid originating at the recirculation line-to-ET interface. A hands-on inspection revealed a 5" x 1" area of subsurface voids with depths that may extend to substrate along the isochem line of the closeout. The IPR was upgraded to a PR and the voids were repaired.

No ice/frost was visible on the LO2 ET/ORB umbilical. No ice was present in the LO2 feedline bellows. Small amounts of ice were present in the aft feedline support brackets.

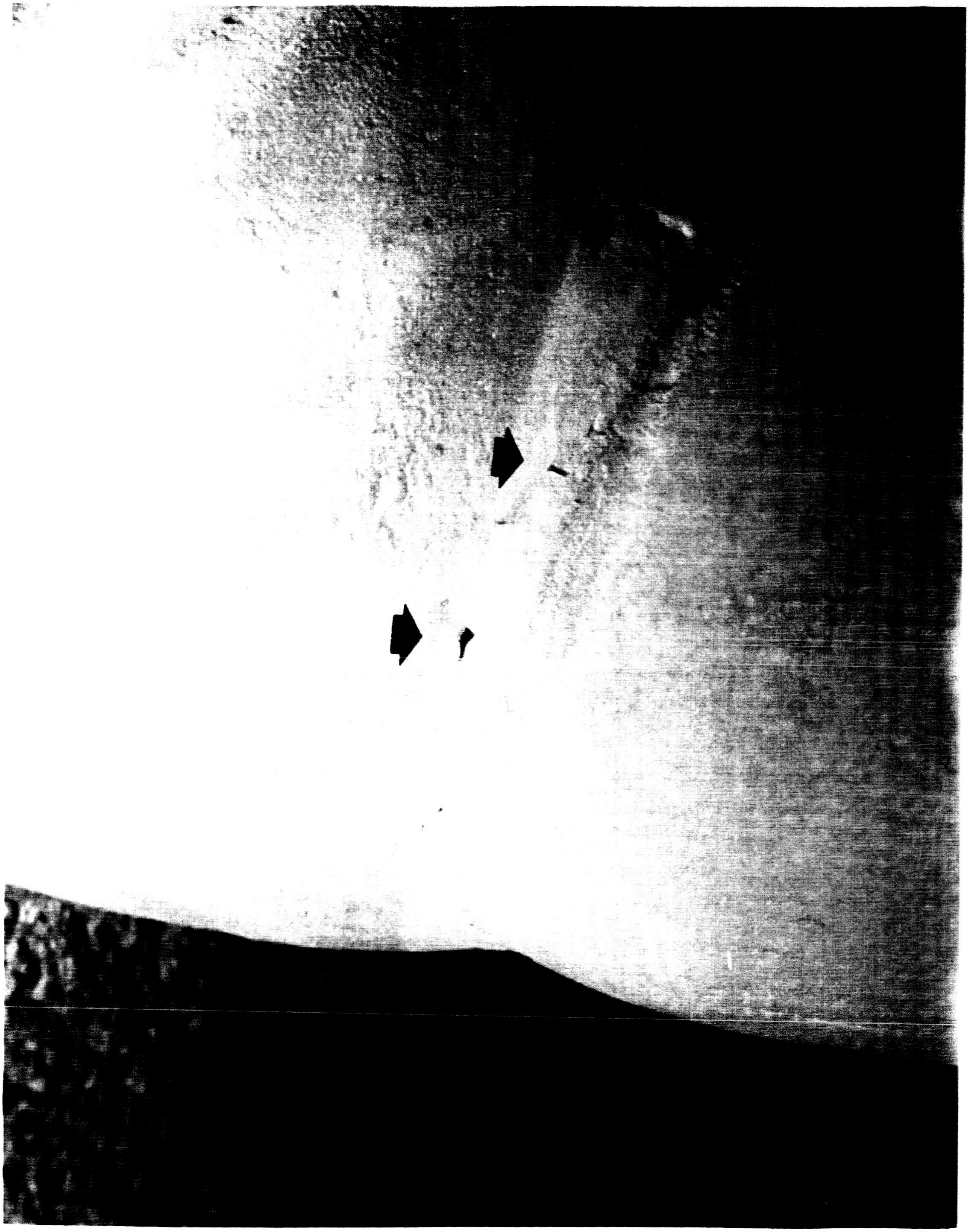
The 1-inch repair in the +Z siphon manhole cover showed no evidence that a frost ball had formed during cryo-loading operations. This condition is acceptable per NSTS-08303.

There was no damage to the Orbiter or SRB TPS. No anomalies were visible on the SSME's.

The SRB sound suppression water troughs were full. The only facility anomaly consisted of a raised (bottomed out) bolt on a small MLP deck access cover west of the LH SRB.



Post drain condition of ET-35 ET/ORB LH2 umbilical TPS



Stream of cryo pumped liquid/drips originated from the 4-inch LH2 recirculation line-to-tank interface from a 5"x1" area of subsurface voids along the isochem line of the TPS closeout.

3.2 TANKING TEST POST DRAIN INSPECTION

A special, limited tanking test of the LH2 tank was conducted on 6 June 1990 in an effort to obtain more data on the hydrogen leak in the Orbiter aft compartment and in the area of the LH2 ET/ORB umbilical 17-inch feedline disconnect. High concentrations of hydrogen reappeared in this area when liquid hydrogen flowed through the 17-inch line. The LH2 tank was filled to approximately the 20 percent level. A post drain inspection of ET-35 was performed at Pad 39A from 1500 to 1600 hours on 6 June 1990.

No damage, such as divots or cracks, were visible on the LH2 tank acreage areas.

There was a 12-inch long crack in the +Y longeron-to-thrust strut TPS interface.

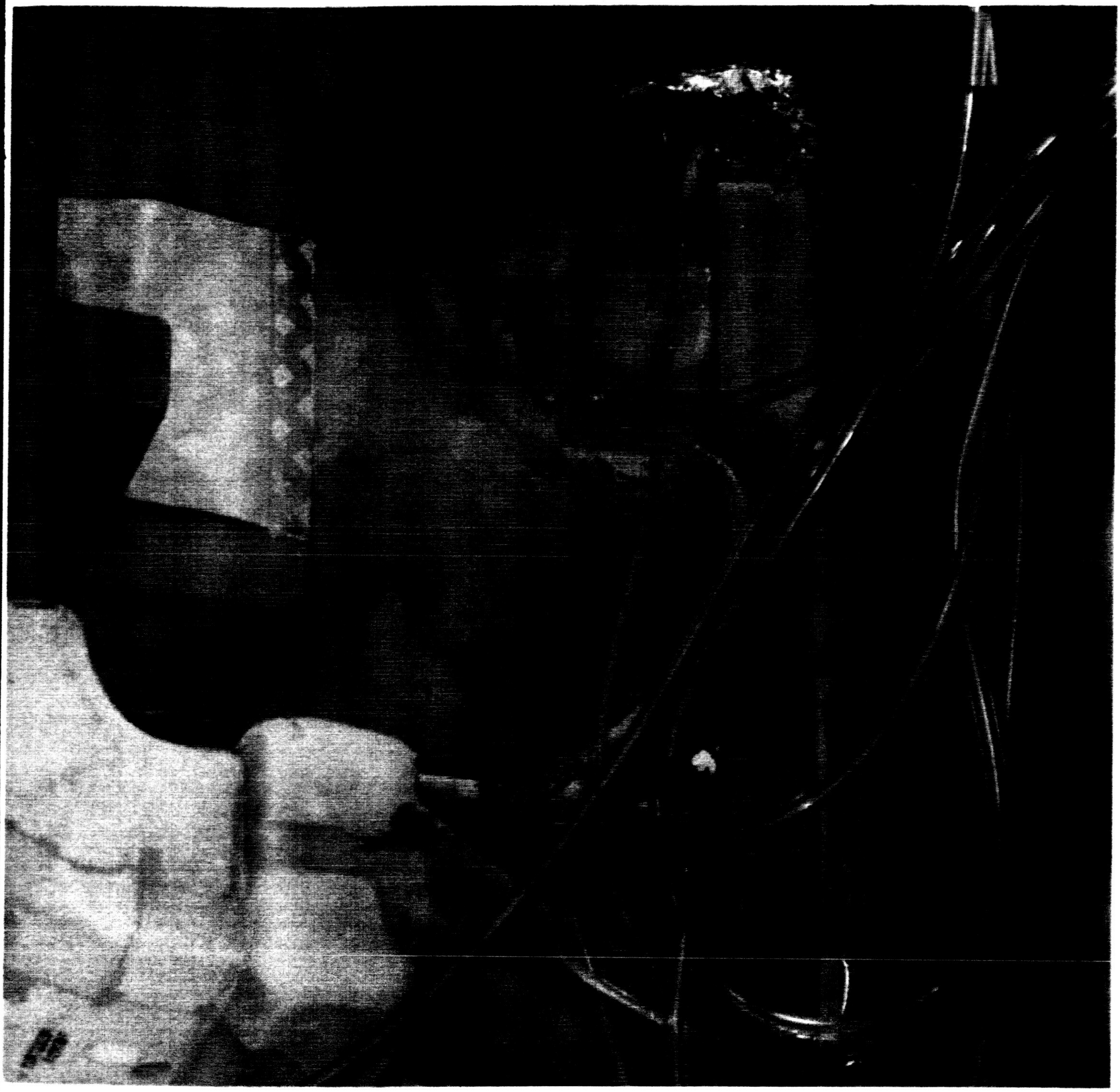
Solid ice was present in both +Y and -Y diagonal strut aft fairing flow restrictors. Ice still remained on EB-7 and EB-8 fittings.

There were no anomalies on the LO2 feedline or LO2 ET/ORB umbilical. A small amount of solid ice remained in the LH2 feedline lower bellows. Some ice remained in the LH2 recirculation line lower bellows and covered both burst disks. The TPS repairs on the recirculation line elbow, where voids to the SLA had caused cryo-pumping during the previous tanking, and on the lower bellows closeout were intact. No ice/frost formations were visible in these areas.

A 1/2-inch diameter frost spot was present on an aft dome PDL plug-pull repair.

There was no damage to the Orbiter or SRB TPS. No anomalies were visible on the SSME's.

All instrumentation tygon tubing was in place. The hydrogen detection system butcher paper was intact.



No anomalies occurred on the LH2 ET/ORB umbilical during the tanking test. Leak detection sensors/tygon tubes were attached to the leak check ports, plate gap purge vents, and pyrotechnic canister purge vents to characterize/locate the hydrogen leak.

3.3 SECOND LAUNCH ATTEMPT SCRUB

Since the hardware containing the hydrogen leak could not be repaired at the launch pad, the STS-35 SSV was rolled back to the VAB. The ET/ORB LH2 umbilical hardware was replaced with a 6000 series umbilical on ET-35 and the OV-105 LH2 umbilical on the OV-102 Orbiter.

The second launch attempt of STS-35 was scrubbed due to high concentrations of hydrogen in the Orbiter aft compartment. The LO2 tank had been filled approximately 15-20 percent. The LH2 tank had been filled to 100 percent. LD54 and LD55 registered very little activity during fill/drain. Hydrogen readings in the aft compartment averaged 5600 ppm, but had at one time peaked at 9910 ppm. A post drain inspection of ET-35 was performed at Pad 39A from 0945 to 1100 hours on 6 September 1990.

No TPS damage, such as divots or cracks on the tank acreage, were visible.

The tumble valve cover exhibited no anomalies. There was no TPS damage to the ET nosecone or fairing. An IPR documented a small area of missing topcoat in the -Y footprint area/grid. The +Y footprint area was not visible from the FSS.

A 10-12 inch long crack appeared in both the +Y and -Y longeron-to-thrust strut TPS interfaces. A TPS crack in this location is acceptable per NSTS-08303.

The hydrogen detection system butcher paper was intact. The GH2 detection system tygon tubing was in the proper position.

There were no visible anomalies on the LO2 feedline support brackets, feedline bellows, or ET/ORB umbilical.

Visually, there were no anomalies on the ET/ORB LH2 umbilical. Formation of frost fingers on the plate gap purge vents and the umbilical pyro canister purge vents during the cryoload had been normal. Ice/frost accumulation on the outboard side of the baggie also had been typical. However, heavier than normal ice/frost accumulation along with upward flowing purge gas vapors had appeared on the top side of the umbilical/baggie. OTV surveillance of the LH2 umbilical revealed a possible crack in the foam just below the forward outboard pyro canister closeout. The crack appeared to extend across the width of the umbilical, but was not coated with ice or frost. Both of these areas were inspected and found to be closeout lines with no TPS damage.

Although a frost ball formation on the aft side of the cable tray support ramp at station XT-1980, and two frost spots on the LH2 tank aft dome (+Y-Z inner circumference of the -Z manhole cover closeout; +Y edge of sanded area between the manhole covers) were documented during the cryoload, no sign of

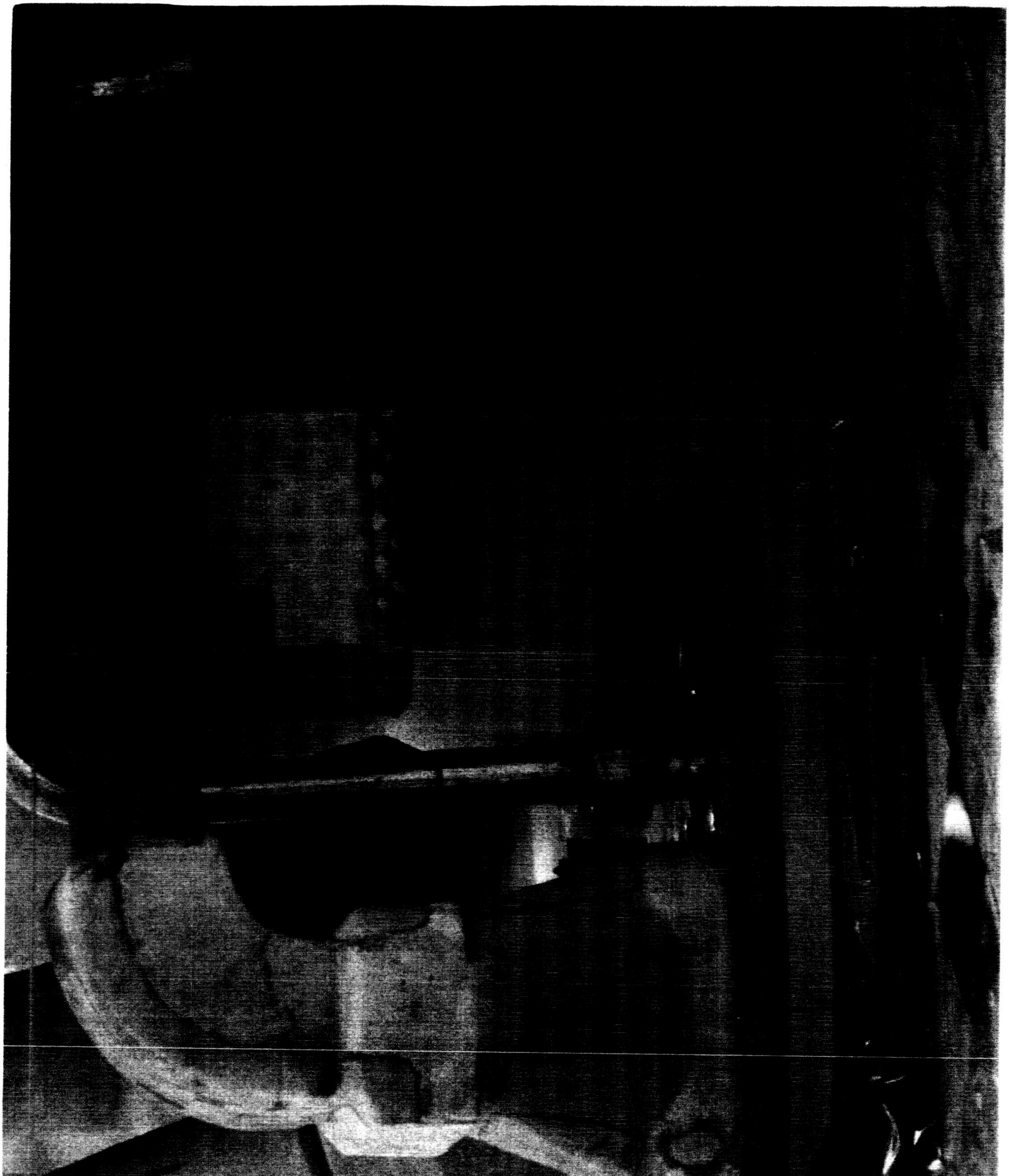
TPS damage was visible during the post drain inspection. The frost formations had occurred in sheltered areas or along isochem bondlines.

All of these conditions had occurred previously on other vehicles and are acceptable per NSTS-08303.

There was no damage to the Orbiter or SRB TPS. No anomalies were visible on the SSME's.

The SRB sound suppression water troughs were full. No facility anomalies were observed.

Prior to this tanking test, a foreign object was discovered embedded in the ET-35 LH2 tank acreage CPR-488 foam in the -Y-Z quadrant at approximate station XT-1852. When removed, the object was a metallic sliver that had penetrated the TPS to a depth of 7/32 inches. Chemical identification analysis by the MAB laboratory revealed a low-alloy steel, steel corrosion, zinc paint coating, and rubberized caulking. The source of the debris was believed to be the GOX vent arm. The repair/removal of the debris source was worked by recurrence control action on IPR 35RV-0283 and PR ET-35-ST-0052. The TPS damage area was accepted for use-as-is by MRB action on August 28, 1990.



No hydrogen leaks or anomalies occurred in the area of the LH2 ET/ORB (new) 6000 series umbilical on ET-35

3.4 THIRD LAUNCH ATTEMPT SCRUB

The third launch attempt of STS-35 was scrubbed on 17 September 1990 due to high concentrations of hydrogen in the Orbiter aft compartment. The new LH2 umbilical hardware, which consisted of the OV-105 LH2 umbilical and an ET 6000 series umbilical, did not produce a leak outside of the vehicle. The LH2 tank was filled to 98 percent. Removable leak detectors LD54 and LD55 registered very little activity during fill/drain. Liquid oxygen had reached fastfill for 10 minutes before the LO2 tank was drained. Hydrogen readings in the aft compartment averaged 3800 ppm, but had at one time peaked at 5750 ppm. In addition, leak detector sensors at the GUCP reached 4% for a time period over 30 minutes and may have been the result of liquid hydrogen entering the vent line during rapid boil-off when the tank was filled to 98%. The high hydrogen readings continued as long as the vent valve was open, but stopped shortly after the valve was closed. Post drain inspection of ET-35 was performed at Pad 39A from 0830 to 1000 hours on 18 September 1990.

No TPS damage, such as divots or cracks on the tank acreage, were visible.

The tumble valve cover exhibited no anomalies. There was no TPS damage to the ET nosecone, fairing, or -Y footprint area/grid. The +Y footprint area was not accessible at this time.

A 10-12 inch long crack was present in both the +Y and -Y longeron-to-thrust strut TPS interfaces. Repair of these cracks was not required and are acceptable per NSTS-08303.

There were no visible anomalies on the LO2 feedline support brackets, feedline bellows, or ET/ORB umbilical.

Visually, there were no anomalies on the ET/ORB LH2 umbilical. Formation of frost fingers on the plate gap purge vents and the umbilical pyro canister purge vents during the cryoload had been normal. Ice/frost accumulation on the top and outboard side of the baggie also had been typical. No discrepancies were visible on the LH2 feedline/bellows and LH2 recirculation line/bellows. The TPS repair on the LH2 feedline-to-tank interface at the 6 o'clock position, discovered during a pre-launch inspection and repaired prior to cryogenic loading, was intact with no anomalies.

Nine Ice/frost console observations/anomalies were documented during the cryoload.

1) Frost spots on the LH2 aft dome manhole (+Z) closeout bondline and adjacent bondline.
2) Vapors and frost formation on the +Z aft LH2 manhole closeout acreage, or 'bump'.
3) Frost formation on the cryoflex panel area adjacent to the aft hardpoint closeout on -Y side bondline.

4) Vapors and frost formation on cracks in the +Y longeron closeout. One crack, shaped like an inverted 'Y', was located at approximate station XT-1970. Frost spots formed at 2 locations on the longeron closeout adjacent to the thrust strut-to-tank joint.
5) Ice/frost formations on the -Y longeron closeout at approximate station XT-1955.
6) Ice/frost formation aft of the cable tray support ice/frost ramps at stations XT-1787 and 1851.
7) Vapors in the vicinity of the GUCP.
8) Vapors and ice/frost formation on cracks in the +Y longeron-to-thrust strut interface.
9) Vapors emanated from the LH2 recirculation line burst disk (tank side).

There was no visible evidence of TPS damage at any of these locations during the post drain inspection. All of these TPS conditions had occurred previously on other vehicles and are acceptable per NSTS-08303.

There was no damage to the Orbiter or SRB TPS. No anomalies were visible on the SSME's.

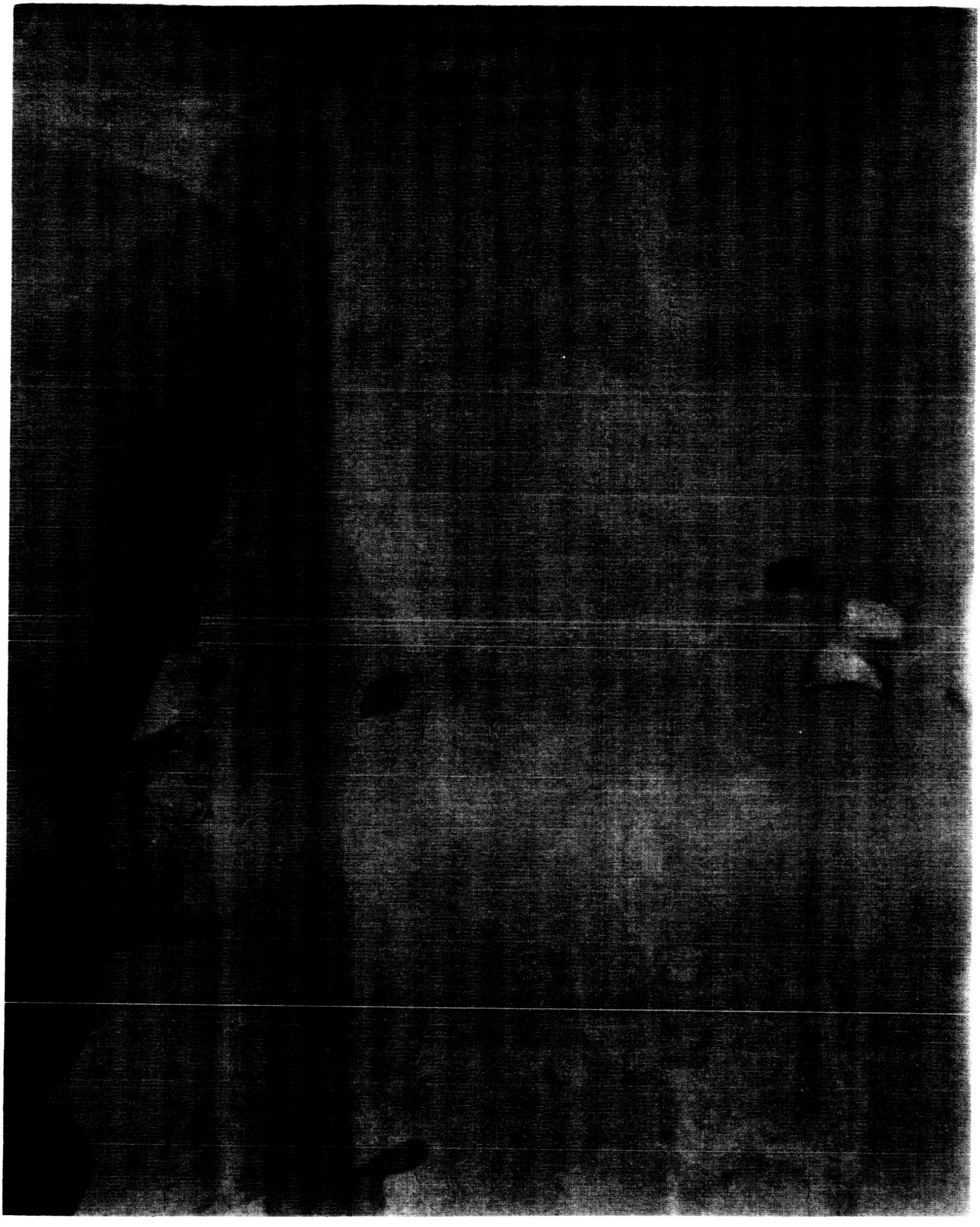
The SRB sound suppression water troughs were full. No facility anomalies were observed.

A more detailed inspection of the ET/ORB umbilicals and the longerons was performed after the Orbiter Weather Protection structure was extended on 19 September 1990. Removable leak detector LD54 and LD55 tygon tubes were in the proper position. No TPS anomalies were visible on either LH2 or LO2 umbilicals. There were no tears or unusual openings in the umbilical purge barrier baggies.

Inspection of both +Y and -Y longerons from a distance of 10-15 feet revealed no discernible cracks, TPS offsets, or divots in the areas where ice/frost had formed during cryoload/drain. There were no previous repairs in these areas.

High concentrations of hydrogen in the area of the GUCP during the cryo load may have been the result of liquid hydrogen entering the vent line during rapid boil-off when the tank was filled to 98%. The GH2 vent line was subsequently disconnected from the ET umbilical carrier plate, the seal replaced, and the whole system reconnected/tested/validated.

Post drain condition of the LH2 ET/ORB umbilical. No hydrogen leaks or anomalies had occurred on the umbilical external to the vehicle during cryo load and drain.



Cracks 10-12 inches long occurred in both +Y and -Y longeron-to-thrust strut interfaces. There were no visible indications of the frost spots that had formed on the longeron closeout during cryo load.

3.5 TANKING TEST POST DRAIN INSPECTION

All flanges and connections in the LH2 lines were checked and bolts re-torqued. Seals were replaced in some cases. ET-35 LH2 tank was filled to 100 percent with normal topping and stable replenish. No liquid oxygen was loaded in the LO2 tank for this test. Additional test fixtures, sensors, baggies, and cameras were installed in the aft compartment to aid in detecting possible hydrogen leaks. Removable leak detectors LD54 and LD55 were also utilized. The tanking test was successful with readings of less than 150 ppm GH2 in the aft compartment. LD54 read 0 ppm GH2 and LD55 peaked at 300 ppm. Due to the late start time of the test, the post drain inspection was performed the following day at Pad 39B from 0830 to 0930 hours on 31 October 1990. No major vehicle or facility anomalies were observed. There were no SRB anomalies. The Orbiter had one minor anomaly with tears in the LH2 umbilical purge barrier baggie.

The ice/frost fingers on the purge vents and venting of the cold helium purge gas had been normal during the tanking test. There was no visible sign of TPS damage on the LH2 umbilical, feedline, recirculation line, or on the 17-inch flapper valve actuator access port plug closeout.

No anomalies occurred in the LO2 feedline support brackets while the LH2 tank was loaded with cryogenic propellant.

There was no visible TPS damage, such as divots or cracks, on the LH2 tank acreage. A total of 14 ice/frost console observations/anomalies had been recorded during the tanking test. These types of ice/frost conditions have been documented on previous vehicles and are acceptable per NSTS-08303.

Anomaly 001 documented vapors on the forward side of the ET/ORB LH2 umbilical in the area of the field-routed tygon tube (tanking test instrumentation). The vapors originated from a tear in the umbilical baggie at this location.

There were no visible TPS defects on the longeron closeouts where frost spots (8 places on the +Y side, 2 places on the -Y side) during the tanking test. Reference anomalies 002 and 009.

Anomaly 003 recorded 2 frost spots on the +Y side of the LH2 aft dome apex bondline/+Z manhole cover.

A 2-inch diameter frost spot formed on the LH2 tank cryo test panel closeout at the forward end of the aft hardpoint (Anomaly 004).

Anomaly 005 documented a frost spot on the -Y longeron closeout above the vertical strut.

Anomaly 006 recorded vapors at the ET GUCP hydrogen vent disconnect/intertank interface. The vapors began after the vent valve opened for LH2 topping.

Cracks were visible in both +Y and -Y thrust strut-to-longeron TPS interfaces (tanking test anomalies 008 and 009).

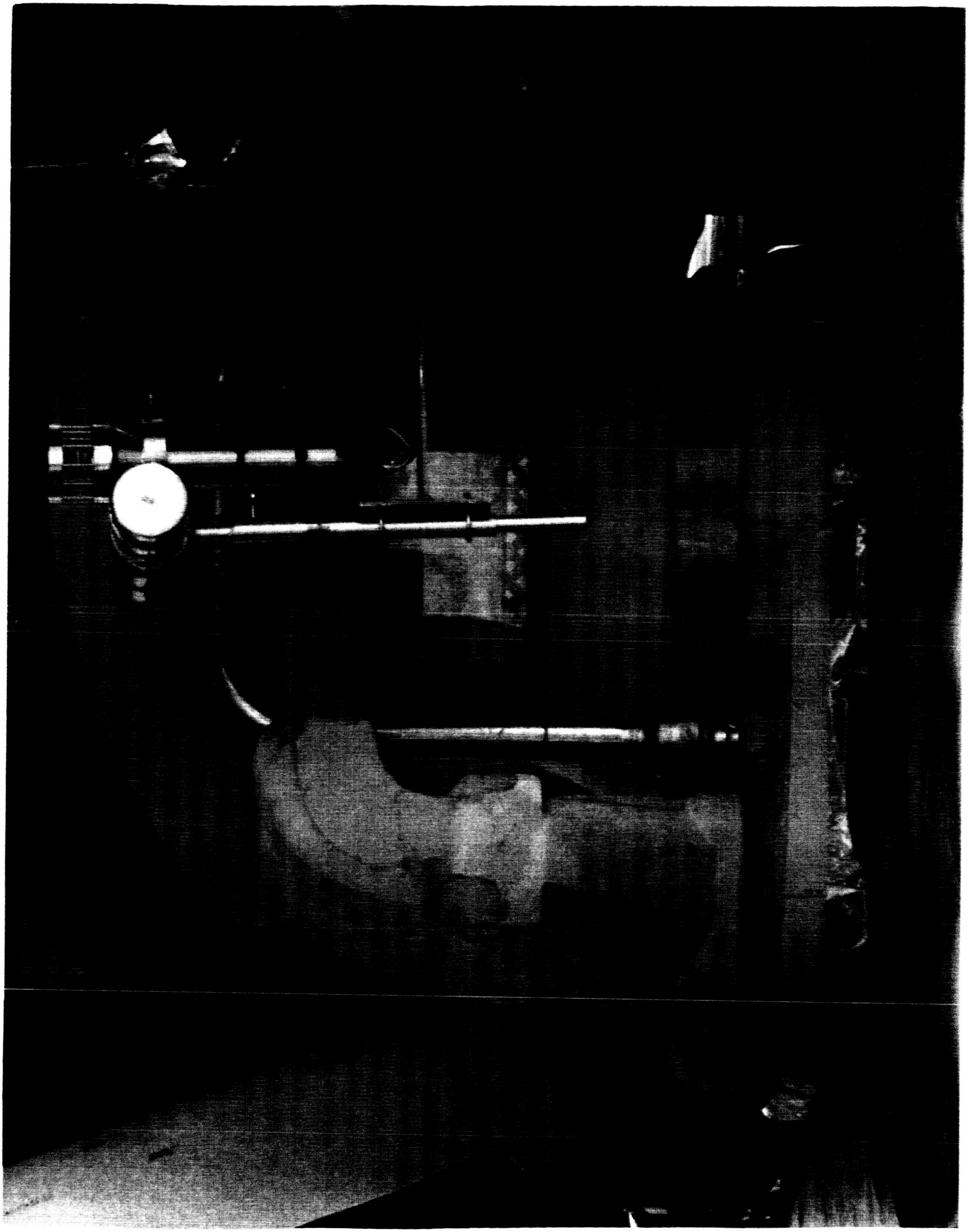
Ice/frost spots formed at the aft sides of the pressurization line/cable tray supports at stations XT-1973, 1787, 1623 (feedline boomerang), 1528, 1270, and 1205 (ref Anomaly 007 and 012).

Anomaly 010 documented vapors emanating from the bipod jack pad closeouts. The bondlines had been exposed during recent repair and closeout.

Anomaly 011 recorded vapors emanating from the LH2 recirculation line lower burst disk and the line-to-LH2 tank aft dome interface during drain.

Ice/frost formed on the LH2 ET/ORB umbilical on the pyro canister purge vents, the forward section of the umbilical baggie, and on the forward inboard leak test port fitting/tygon tube (Anomaly 013).

Anomaly 014 documented ice/frost spots at 3 locations on the -Z aft dome manhole cover closeout.



No anomalies occurred on the LH2 ET/ORB umbilical during the tanking test. Anemometer (attached to the ET fitting) was used to measure local wind/flow fields in the area of the umbilical.

4.0 PRE-TEST BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 30 November 1990 at 1330 hours with the following key personnel present:

A. Oliu	NASA - KSC	ET Processing, Ice/Debris
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
G. Katnik	NASA - KSC	Lead, Ice/Debris Assess Team
S. Higginbotham	NASA - KSC	STI, Ice/Debris Assessment
B. Davis	NASA - KSC	STI, Ice/Debris Assessment
B. Speece	NASA - KSC	ET Processing, Ice/Debris
B. Bowen	NASA - KSC	ET Processing, Ice/Debris
K. Tenbusch	NASA - KSC	ET Processing, Ice/Debris
J. Rivera	NASA - KSC	ET Processing, Debris Assess
M. Bassignani	NASA - KSC	ET Processing, Debris Assess
J. Hoffman	LSOC - SPC	ET Processing, Ice Assess
R. Seale	LSOC - SPC	ET Processing, Ice Assess
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
J. McClymonds	RI - DNY	Debris Assess, LVL II Integ
T. Thorson	RI - LSS	Vehicle Integration
S. Otto	MMC - LSS	ET Processing
L. Clark	USBI - LSS	SRB Processing
M. Nowling	MTI - LSS	SRM Processing
K. Parsons	MTI - LSS	SRM Processing
R. Lovelace	LSOC - SPC	Safety

These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

4.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 30 November 1990 from 1430 - 1530 hours. The detailed walkdown of Launch Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (10th flight), ET-35 (LWT-28), and BI038. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

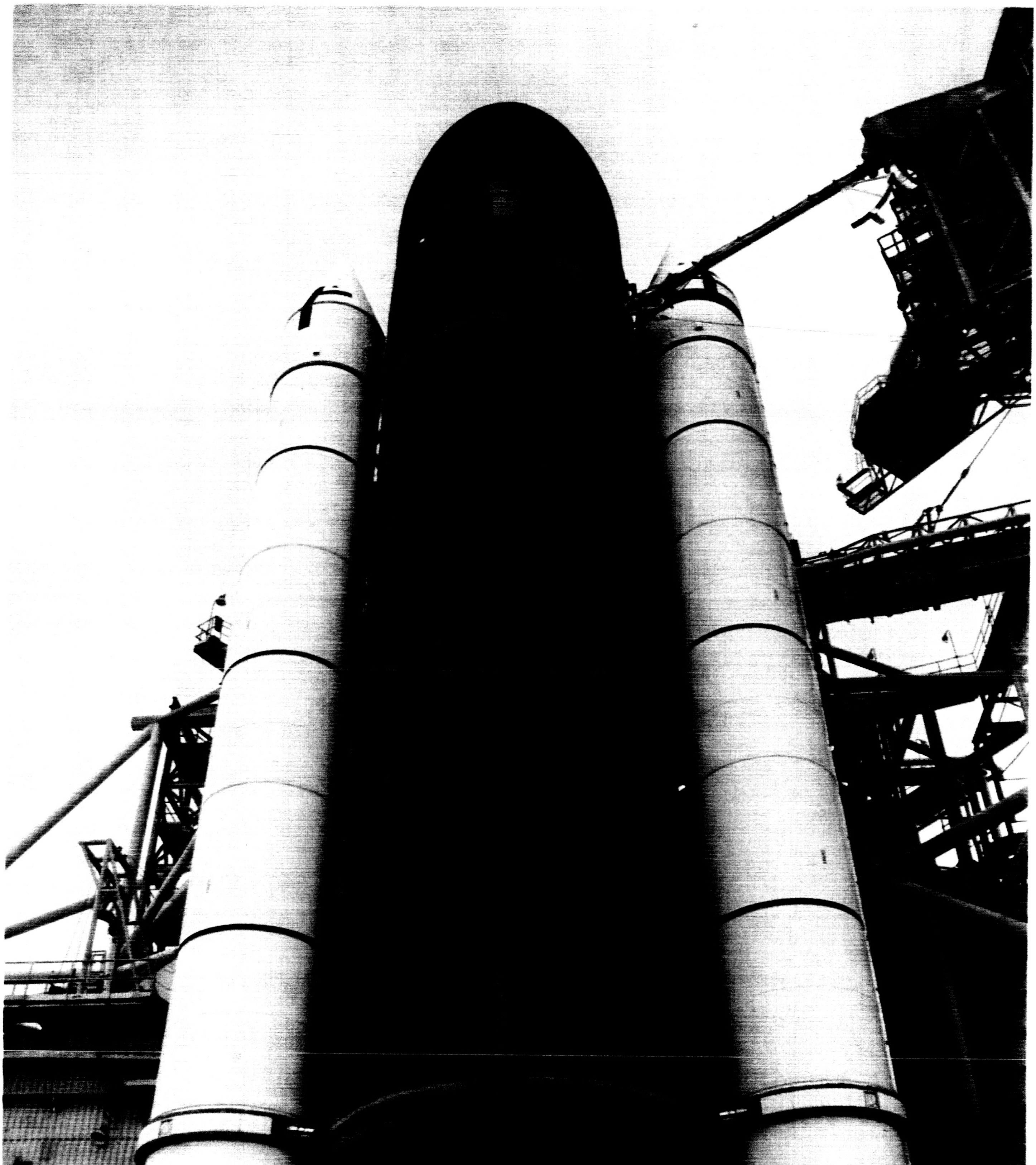
There were no major vehicle anomalies. Minor discrepancies on the vehicle included two bare metal areas above the RH SRB IEA and a small piece of K5NA attached to the forward side of the LH SRB phenolic kick ring at the +Z axis.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/ launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor can be designed and installed. The tygon tubes are intended to remain in place during cryo loading and be removed by the Ice Inspection Team during the T-3 hour hold.

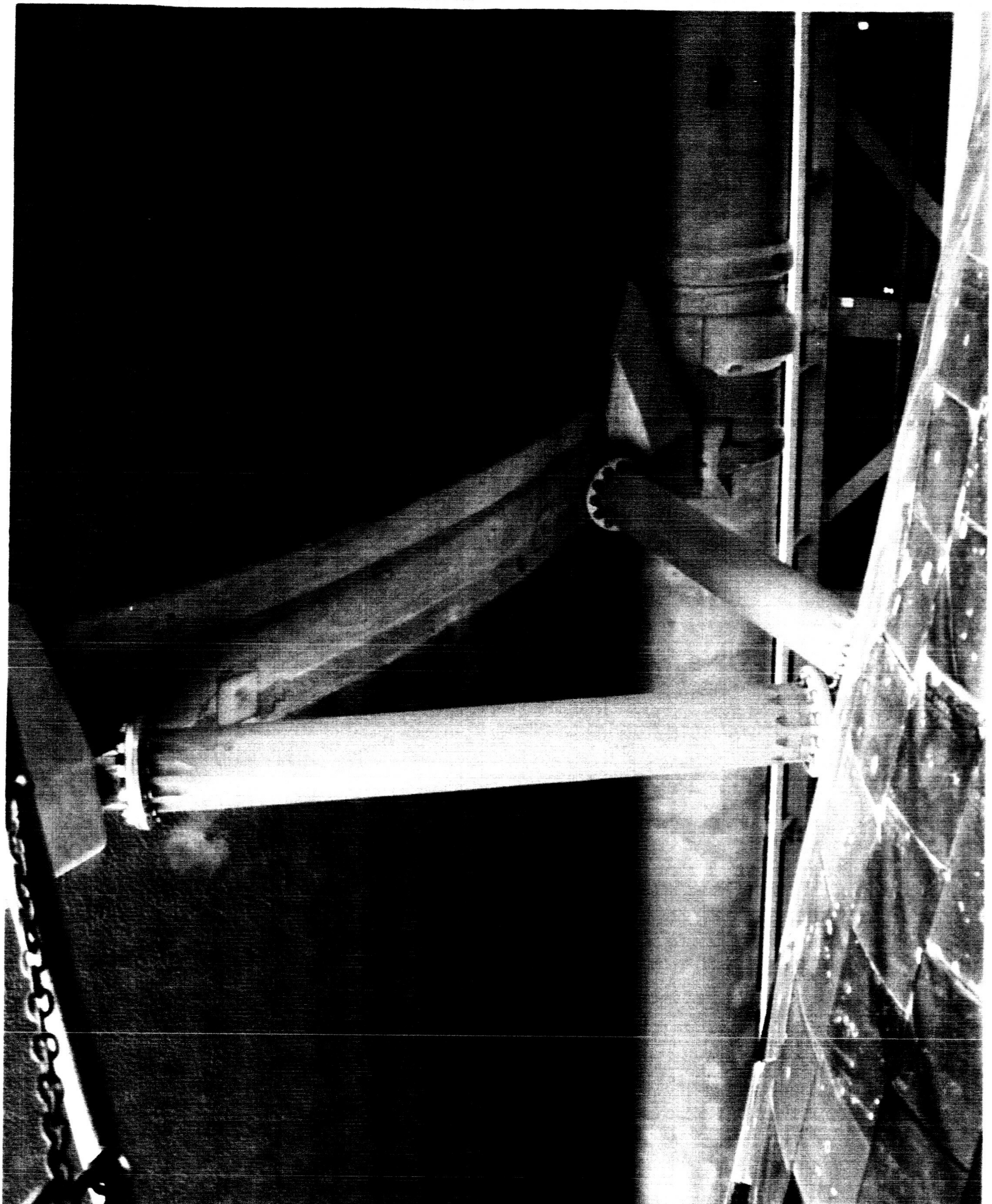
A recurring problem is loose MLP deck bolts. This inspection revealed loose deck bolts around the SRB exhaust holes.

A sound suppression water trough, second from the north side of the LH SRB exhaust hole, was ripped and blowing in the wind. The water trough was replaced and filled with water prior to cryo load.

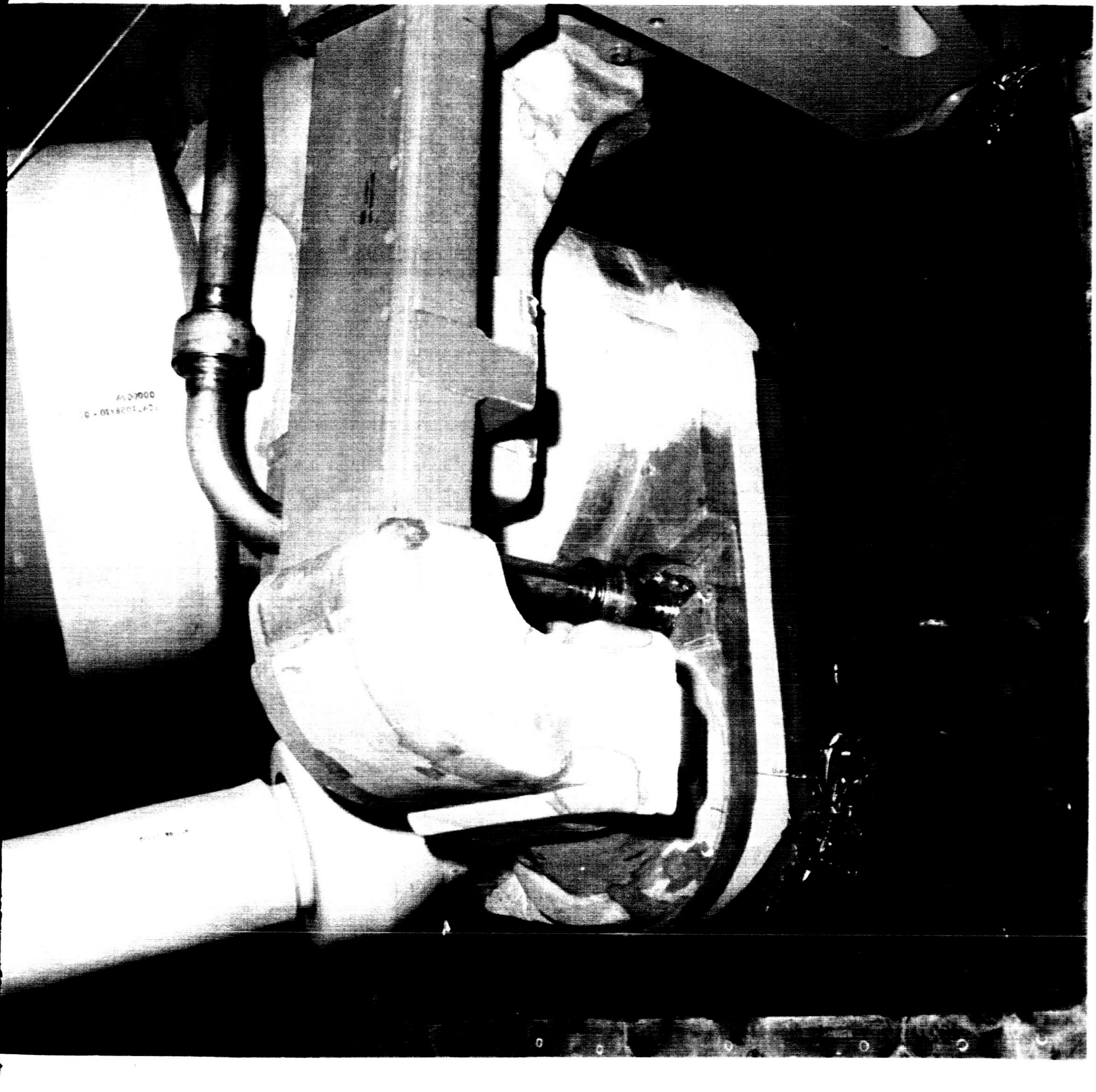
Cleanup of the MLP deck and pad surface was progressing at the time of the inspection. The facility discrepancies were worked real-time or entered into S0007 Appendix K for resolution prior to vehicle tanking.



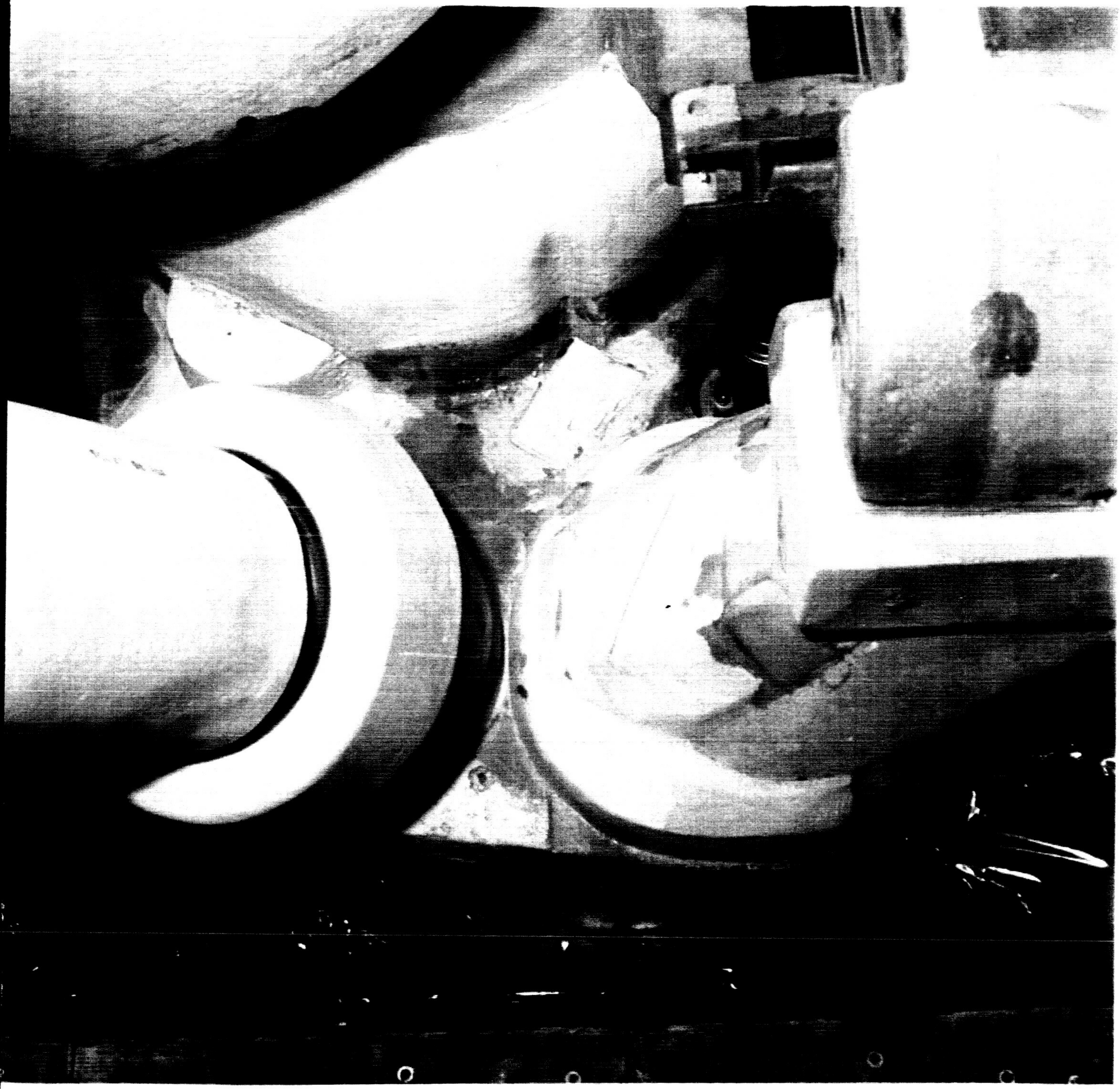
Overall view of ET-35 (LWT 28) and BI038 SRB's -Z side



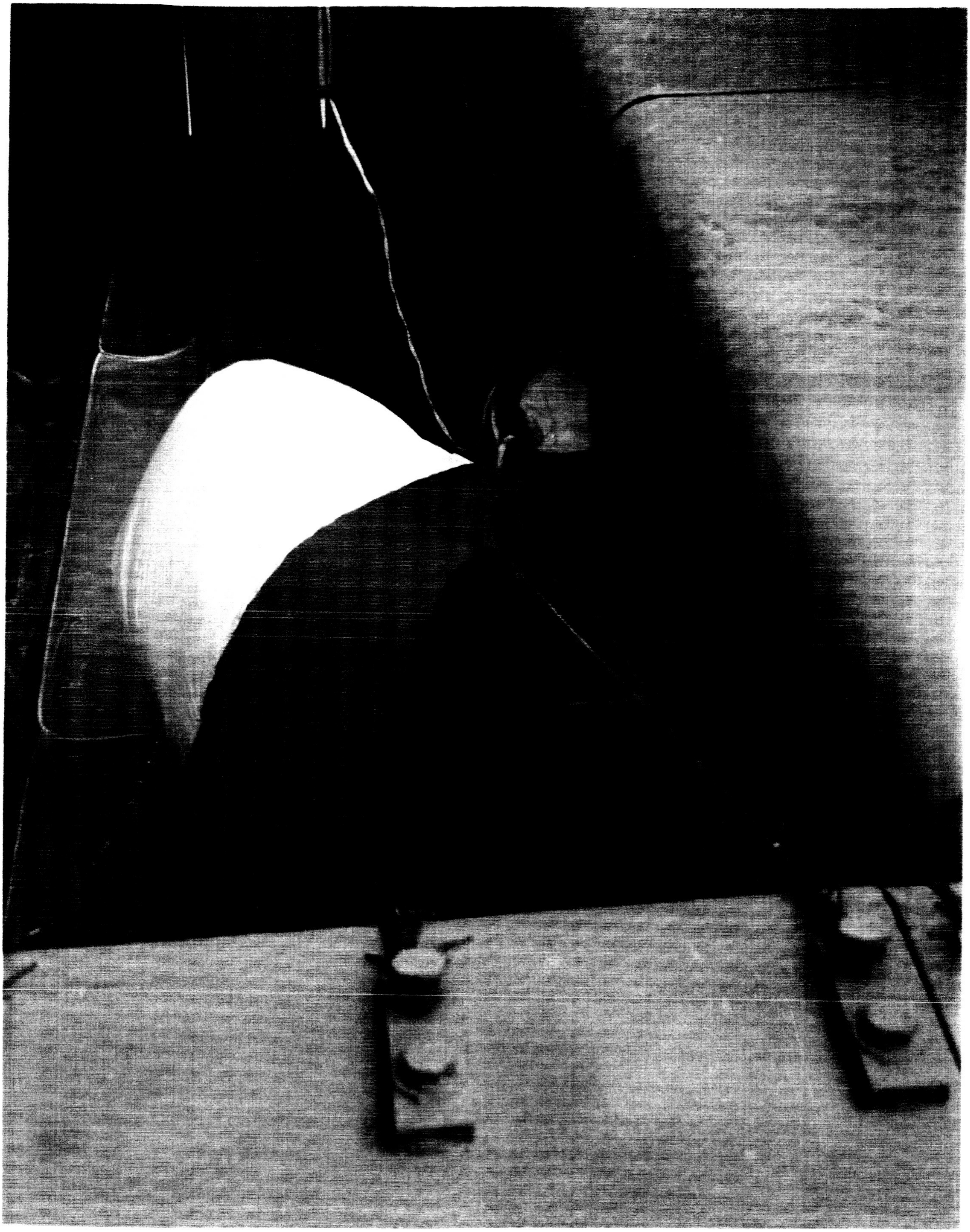
Pre-launch configuration of intertank/upper LH2 tank acreage TPS. Black markings show location of drilled vent holes.



Pre-launch configuration of LH2 ET/ORB umbilical. OV-102 carried 5mm and 10mm focal length 16mm cameras to record SRB and ET separation. The LO2 umbilical was equipped with a 35mm camera to record ET separation.



LH2 umbilical 17-inch flapper valve tool access port foam plug closeout appeared to have a small resin sealant void, or crack, at the top corner near the 17-inch LH2 feedline.



This torn sound suppression water trough at the north edge of the LH SRB exhaust hole was replaced prior to launch

5.0 LAUNCH

STS-35 was launched at 2:06:49:01 GMT on 2 December 1990.

5.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 1 December 1990 from 2105 to 2330 hours during the two hour built-in-hold at T-3 hours in the countdown. An IPR was taken against a 24-30 inch intertank TPS crack, but was dispositioned to fly-as-is. This crack was a violation of a top level TPS configuration/CPR application drawing. There were no Launch Commit Criteria or NSTS-08303 violations. Ambient weather conditions at the time of the inspection were:

Temperature:	71.7 F
Relative Humidity:	55.2 %
Wind Speed:	14 Knots
Wind Direction:	92 Degrees

The portable STI infrared scanner was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figure 1 and 2.

5.2 ORBITER OBSERVATIONS

No Orbiter tile anomalies were observed. The average Orbiter surface temperature was 70 degrees F. The average surface temperatures of the SSME engine mounted heat shields were measured at 69 degrees F for SSME #1, 67 degrees F for SSME #2, and 68 degrees F for SSME #3. The coldest spot on the engine mounted heat shields was 44 degrees F. A small iceball was present on the SSME #2 engine mounted heat shield at the 2 o'clock position. All of the SSME heat shields were dry with no condensate. No LO2 vapors originated from inside the SSME nozzles. There was no condensate on the base heat shield tiles.

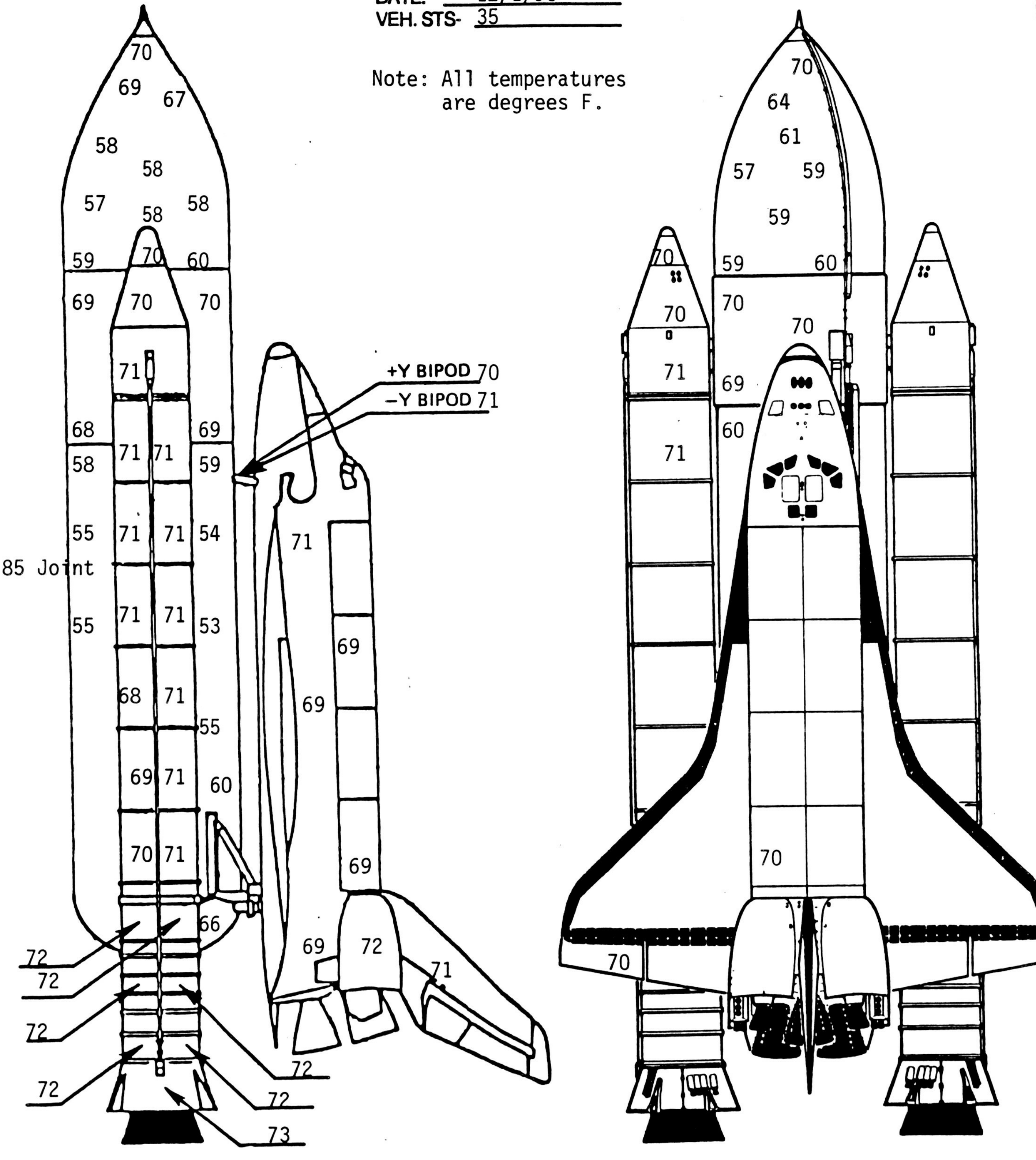
5.3 SRB OBSERVATIONS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 69 and 71 degrees F. Temperatures in the area of the SRB field joint heaters averaged 71 degrees F. The GEI gave measurements of 70 degrees F in comparison. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 71 degrees F, which was within the required range of 44-86 degrees F.

FIGURE 1. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 2105 - 2330
DATE: 12/1/90
VEH. STS- 35

Note: All temperatures are degrees F.

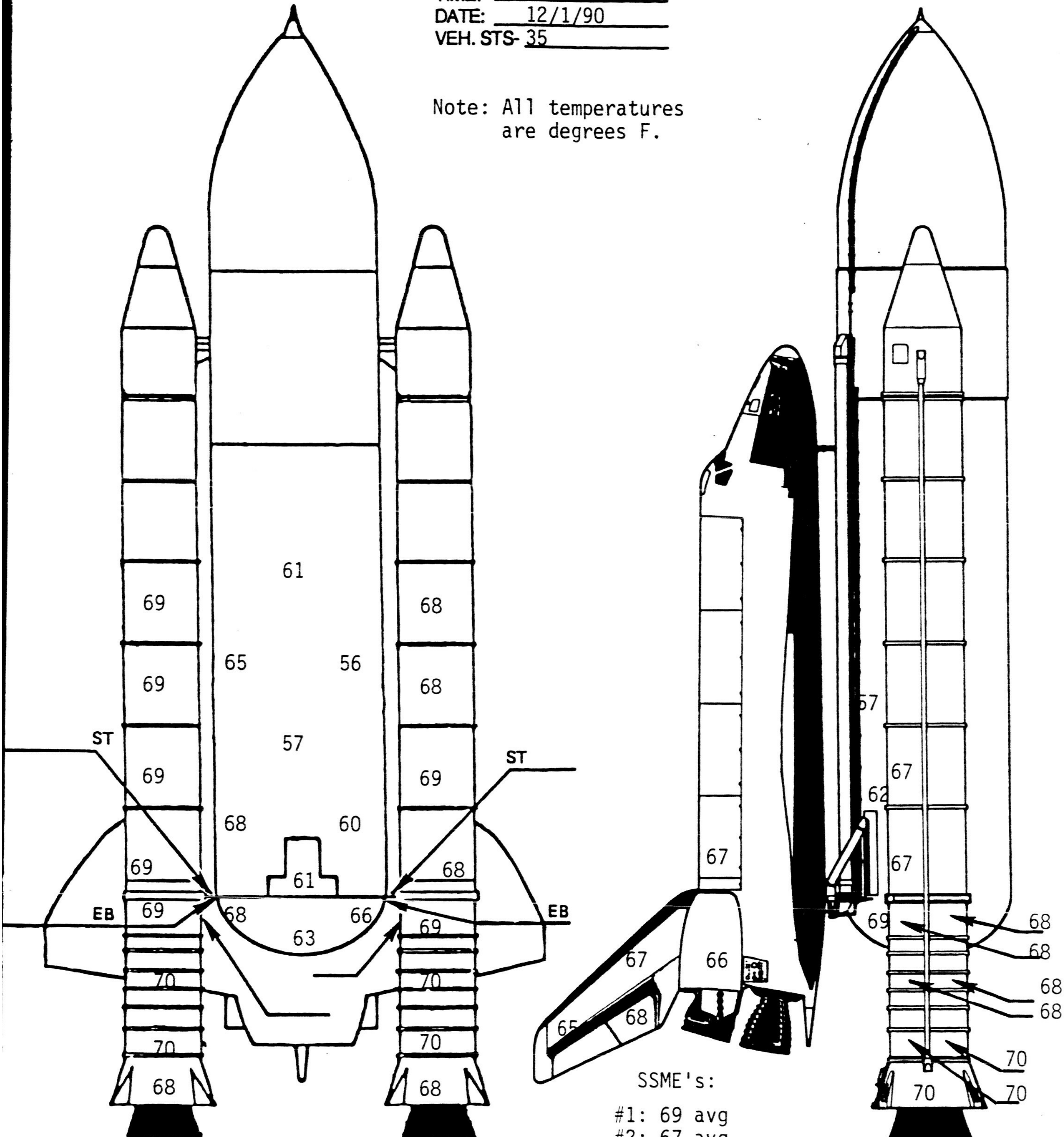


EGG/V-343D

FIGURE 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 2105 - 2330
DATE: 12/1/90
VEH. STS- 35

Note: All temperatures are degrees F.



SSME's:

#1: 69 avg
#2: 67 avg
#3: 68 avg
Coldest spot: 44

5.4 EXTERNAL TANK OBSERVATIONS

The ice/frost prediction computer program 'SURFICE' was run from 1745 to 0149 hours and the results tabulated in Figures 3 and 4. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

Very light condensate was present on the LO2 tank barrel TPS +Z side acreage. There was no ice/frost or condensate on the ogive. There were no TPS or GOX seal anomalies. The tumble valve cover was intact. The STI infrared scanner measured an average surface temperature of 67 degrees F on the ogive and 59 degrees F on the barrel section. SURFICE predicted 61 degrees F on the ogive and 55 degrees F on the barrel section.

The intertank TPS acreage was dry with no condensate. An IPR was taken against a 24-30 inch crack in the first stringer valley on the GUCP side of the -Y thrust panel. The crack was 1/4-inch wide, appeared to go to substrate, had no offset, and was not filled with ice or frost. Similar cracks have occurred in this location on STS-6 (LWT 1) and STS-29R (LWT 29). Very small 1/2-inch diameter frost spots appeared in the stringer valleys near both LH2 and LO2 tank-to-intertank flanges on the -Y-Z side of the tank. Two similar frost spots were present on the -Y+Z LH2 tank-to-intertank flange closeout. The STI IR scanner measured an average surface temperature of 69 degrees F.

The LH2 tank and aft dome TPS acreage exhibited very light condensate. There was no acreage ice/frost and no TPS anomalies. The average surface temperatures as measured by the STI IR scanner were 56 degrees F on the upper LH2 tank and 63 degrees F on the lower LH2 tank. SURFICE predicted 53 degrees F on the upper LH2 tank and 60 degrees F on the lower LH2 tank.

There were no anomalies on the bipods, PAL ramp, cable tray/press line ice/frost ramps, thrust struts, or aft dome apex with the exception of 5 small ice/frost spots on the trailing edge of the ice/frost ramps (3 at the top and 2 at the bottom). Three small frost spots on the -Z manhole cover had melted by the end of the inspection. A crack in the TPS was visible in the -Y thrust strut to tank interface. Eight frost spots had formed on the +Y longeron TPS; 1 large and 4 small frost spots had formed on the -Y longeron TPS. Ice/frost was present in the ET/SRB cable tray-to-upper strut fairing expansion joint. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry. Three ice/frost spots had formed on the aft hardpoint closeout.

Normal amounts of ice were present in all LO2 feedline bellows. Less than usual amounts of ice/frost were present in the LO2 feedline support brackets.

STS- 35	TEST S0007 LAUNCH																			DATE: 2 Dec 1990			T-0 TIME 06:49:01 DATE 12/2/90		
ORBITER 102	ET 35	SRB BI-035	MLP 3	PAD B		LO2 CHILLDOWN TIME: 22:15 SLOW FILL TIME: 23:38				FAST FILL TIME: 23:50 REPLENISH TIME: 02:00					LH2 CHILLDOWN TIME: 22:03 SLOW FILL TIME: 22:21					FAST FILL TIME: 22:38 REPLENISH TIME: 00:38					
TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
1745	71.80	53.20	54.20	15	97	I	8.85	59.79	0.0000	-0.2093	II	8.85	53.96	0.0001	-0.1797	II	8.25	53.01	0.0007	-0.1620	I	18.30	60.04	0.0000	-0.3710
1800	71.60	54.40	54.62	15	97	I	8.85	59.61	0.0000	-0.2108	II	8.85	54.10	0.0003	-0.1811	II	8.25	53.15	0.0008	-0.1633	I	18.30	59.84	0.0000	-0.3738
1815	71.80	53.80	54.51	15	90	I	8.85	59.81	0.0000	-0.2110	II	8.85	54.13	0.0002	-0.1813	II	8.25	53.18	0.0008	-0.1635	I	18.30	60.04	0.0000	-0.3741
1830	71.80	53.40	54.30	13	90	I	7.67	58.71	0.0000	-0.1844	II	7.67	53.21	0.0006	-0.1551	II	7.15	52.15	0.0010	-0.1390	I	15.86	58.76	0.0000	-0.3218
1845	71.80	54.40	54.81	19	89	I	11.21	61.49	0.0000	-0.2638	I	11.21	56.21	0.0000	-0.2333	II	10.45	54.69	0.0001	-0.2122	I	23.18	61.95	0.0000	-0.4785
1900	72.00	56.80	56.19	17	90	I	10.03	60.98	0.0000	-0.2481	II	10.03	55.80	0.0003	-0.2177	II	9.35	54.94	0.0008	-0.1975	I	20.74	61.30	0.0000	-0.4459
1915	71.80	57.20	56.19	19	88	I	11.21	61.57	0.0000	-0.2735	I	11.21	56.26	0.0000	-0.2427	II	10.45	55.45	0.0006	-0.2209	I	23.18	61.98	0.0000	-0.4966
1930	71.60	57.00	55.90	20	86	I	11.80	61.70	0.0000	-0.2834	I	11.80	56.58	0.0000	-0.2526	II	11.00	55.47	0.0003	-0.2301	I	24.40	62.16	0.0000	-0.5168
1945	71.80	57.40	56.29	17	80	I	10.03	60.80	0.0000	-0.2478	II	10.03	55.77	0.0004	-0.2174	II	9.35	54.90	0.0009	-0.1972	I	20.74	61.12	0.0000	-0.4454
2000	71.60	57.40	56.09	17	82	I	10.03	60.60	0.0000	-0.2456	II	10.03	55.57	0.0004	-0.2152	II	9.35	54.71	0.0009	-0.1951	I	20.74	60.92	0.0000	-0.4415
2015	71.60	57.40	56.09	17	73	I	10.03	60.60	0.0000	-0.2456	II	10.03	55.57	0.0004	-0.2152	II	9.35	54.71	0.0009	-0.1951	I	20.74	60.92	0.0000	-0.4415
2030	71.60	58.00	56.38	17	88	I	10.03	60.62	0.0000	-0.2474	II	10.03	55.73	0.0005	-0.2170	II	9.35	54.87	0.0010	-0.1968	I	20.74	60.93	0.0000	-0.4450
2045	71.60	58.40	56.57	16	82	I	9.44	60.19	0.0000	-0.2353	II	9.44	55.53	0.0007	-0.2051	II	8.80	54.62	0.0012	-0.1857	I	19.52	60.43	0.0000	-0.4209
2100	71.80	55.40	55.31	18	89	I	10.62	61.15	0.0000	-0.2544	I	10.62	55.68	0.0000	-0.2240	II	9.90	54.67	0.0004	-0.2034	I	21.96	61.55	0.0000	-0.4594
2115	72.20	53.60	54.79	17	85	I	10.03	61.09	0.0000	-0.2401	I	10.03	55.42	0.0000	-0.2100	II	9.35	54.26	0.0003	-0.1903	I	20.74	61.47	0.0000	-0.4309
2130	72.20	52.00	53.96	17	88	I	10.03	61.06	0.0000	-0.2350	I	10.03	55.40	0.0000	-0.2050	II	9.35	53.81	0.0001	-0.1857	I	20.74	61.45	0.0000	-0.4214
2145	72.20	52.40	54.17	17	89	I	10.03	61.07	0.0000	-0.2362	I	10.03	55.39	0.0000	-0.2062	II	9.35	53.92	0.0002	-0.1869	I	20.74	61.46	0.0000	-0.4238
2200	71.60	54.00	54.42	13	89	I	7.67	58.53	0.0000	-0.1841	II	7.67	53.18	0.0007	-0.1549	II	7.15	52.11	0.0011	-0.1388	I	15.86	58.56	0.0000	-0.3215
2215	71.60	52.80	53.80	18	90	I	10.62	60.88	0.0000	-0.2436	I	10.62	55.42	0.0000	-0.2135	II	9.90	53.76	0.0000	-0.1936	I	21.96	61.33	0.0000	-0.4395
2300	71.60	57.20	56.00	17	97	I	10.03	60.60	0.0000	-0.2449	II	10.03	55.52	0.0003	-0.2146	II	9.35	54.65	0.0009	-0.1946	I	20.74	60.92	0.0000	-0.4404
2315	71.40	60.60	57.40	15	108	I	8.85	59.59	0.0000	-0.2261	II	8.85	55.58	0.0012	-0.1958	II	8.25	54.62	0.0017	-0.1770	I	18.30	59.72	0.0000	-0.4022
2330	71.00	58.80	56.18	14	97	I	8.26	58.63	0.0000	-0.2039	II	8.26	54.30	0.0011	-0.1741	II	7.70	53.30	0.0016	-0.1566	I	17.08	58.72	0.0000	-0.3599
2345	71.20	58.60	56.28	15	95	I	8.85	59.34	0.0000	-0.2185	II	8.85	54.85	0.0009	-0.1885	II	8.25	53.89	0.0014	-0.1701	I	18.30	59.52	0.0000	-0.3884
0000	71.40	59.00	56.66	15	97	I	8.85	59.56	0.0000	-0.2216	II	8.85	55.15	0.0010	-0.1916	II	8.25	54.19	0.0015	-0.1730	I	18.30	59.70	0.0000	-0.3940
0015	71.60	58.80	56.76	14	104	I	8.26	59.23	0.0000	-0.2096	II	8.26	54.91	0.0011	-0.1797	II	7.70	53.91	0.0016	-0.1619	I	17.08	59.30	0.0000	-0.3699
0030	71.60	59.80	57.22	16	94	I	9.44	60.24	0.0000	-0.2395	II	9.44	55.91	0.0009	-0.2091	II	8.80	55.00	0.0014	-0.1894	I	19.52	60.45	0.0000	-0.4286

FIGURE 3. 'SURFICE' Computer Predictions

STS- 35 | TEST S0007 LAUNCH | DATE: 2 Dec 1990 | T-0 TIME 06:49:01 DATE 12/2/90

ORBITER 102 | ET 35 | SRB BI-035 | MLP 3 | PAD B

LO2 — CHILLDOWN TIME: 22:15 FAST FILL TIME: 23:50 SLOW FILL TIME: 23:38 REPLENISH TIME: 02:00

LH2 — CHILLDOWN TIME: 22:03 FAST FILL TIME: 22:38 SLOW FILL TIME: 22:21 REPLENISH TIME: 00:38

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0045	71.60	60.40	57.50	15	96	I	8.85	59.78	0.0000	-0.2276	II	8.85	55.73	0.0012	-0.1973	II	8.25	54.77	0.0017	-0.1784	I	18.30	59.91	0.0000	-0.4048
0100	71.40	61.40	57.76	17	94	I	10.03	60.50	0.0000	-0.2557	II	10.03	56.44	0.0010	-0.2250	II	9.35	55.58	0.0015	-0.2043	I	20.74	60.77	0.0000	-0.4606
0115	71.00	63.40	58.25	14	90	I	8.26	58.76	0.0000	-0.2158	II	8.26	55.52	0.0017	-0.1856	II	7.70	54.50	0.0022	-0.1673	I	17.08	58.76	0.0000	-0.3817
0138	71.00	63.80	58.43	12	95	II	7.08	58.07	0.0002	-0.1887	II	7.08	54.69	0.0020	-0.1589	II	6.60	53.55	0.0024	-0.1423	I	14.64	57.99	0.0005	-0.3282
0149	71.20	63.00	58.27	14	90	I	8.26	58.96	0.0000	-0.2167	II	8.26	55.62	0.0017	-0.1865	II	7.70	54.60	0.0021	-0.1682	I	17.08	58.95	0.0000	-0.3833
AVG	63.42	46.67	46.9	13.7	E		7.89	56.47				8.34	51.91				7.78	49.43				17.25	53.45		

Period of Ice Team Inspection

FIGURE 4. 'SURFICE' Computer Predictions

There were no anomalies on the LO2 ET/ORB umbilical. The baggie was configured properly and was holding positive purge pressure. A small amount of ice/frost covered the inboard areas of the baggie. There was no ice/frost accumulation on the acreage areas of the umbilical. Ice/frost fingers 6-7 inches in length had formed on the three pyro canister purge vents. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

Ice/frost had formed in the LH2 recirculation line bellows and on both burst disks. The lower LH2 feedline bellows was filled with frost while the upper bellows was wet with condensate. The top and sides of the LH2 ET/ORB umbilical were covered by heavy, but typical, ice/frost. Ice/frost accumulation on the inboard and aft areas of the baggie was light. Ice/frost fingers 4-5 inches in length had formed on the pyro canister purge vents. Normal venting of helium purge gas had occurred during tanking, stable replenish, and launch. There were no unusual vapors emanating from the umbilicals nor any evidence of cryogenic drips. No frost was visible on the cable tray vent hole. Two small frost spots had formed on the LH2 feedline-to-tank interface outboard side. The 17-inch flapper valve actuator access port foam plug was properly closed out with no ice/frost on the bondline.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle with no contact or TPS damage.

The summary of ice/frost team observation anomalies consists of 9 OTV recorded items:

Anomaly 001 documented ice/frost spots on the aft hardpoint closeout along the bondlines and knit lines. This condition was acceptable per NSTS-08303.

Anomaly 002 recorded numerous ice/frost accumulations on the +Y longeron TPS along knit lines, bondlines, or in the thrust strut interface. This accumulations were acceptable per NSTS-08303.

Numerous ice/frost accumulations occurred on the -Y longeron TPS along knit lines and bondlines (Anomaly 003). Vapors emanated from the largest frost spot, which eventually formed ice. These accumulations were acceptable per NSTS-08303.

Anomaly 004 documented ice/frost in the LO2 feedline bellows and support brackets. Ice/frost accumulations also occurred at the trailing edge of the pressurization line ramp at station XT-1205, the cable tray ramp XT-1722, and the cable tray support XT-1980. The ice/frost was acceptable for these locations per NSTS-08303.

Anomaly 005 recorded frost accumulation on the GUCP legs and was acceptable per NSTS-08303.

The 24-30 inch crack in the intertank TPS in the first stringer valley on the GUCP side of the -Y thrust panel was documented on Anomaly 006 and IPR 35RV-400. The crack was 1/4-inch wide, exhibited no offset, and was not filled with ice/frost. After upgrading to PR ET-35-TS-0112, the condition was accepted for flight by MRB approval.

Anomaly 007 documented 2 frost spots on the -Z manhole cover and were acceptable per NSTS-08303.

Anomaly 008 recorded ice/frost accumulations on the LH2 ET/ORB umbilical purge barrier (baggie), purge vents, LH2 feedline bellows, LH2 recirculation line bellows and burst disks. Froth was observed by the Ice Team at the recirculation line-to-aft dome closeout interface. All of these conditions were acceptable per NSTS-08303.

Ice/frost accumulations on the LO2 ET/ORB umbilical purge vents and purge barrier (baggie) was documented on Anomaly 009 and acceptable for flight per NSTS-08303.

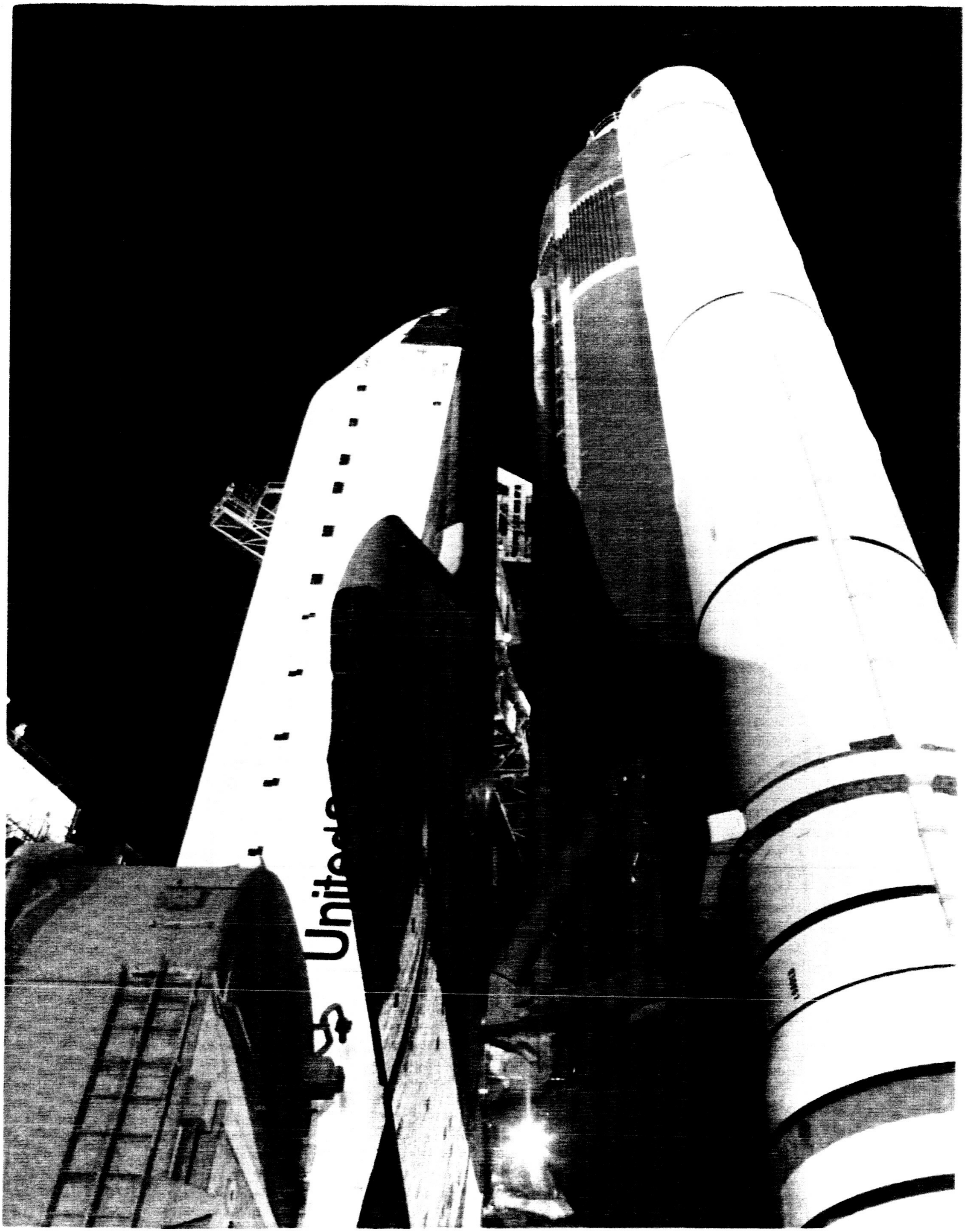
5.5 FACILITY OBSERVATIONS

No new debris concerns had been identified during the ice/frost inspection of the vehicle.

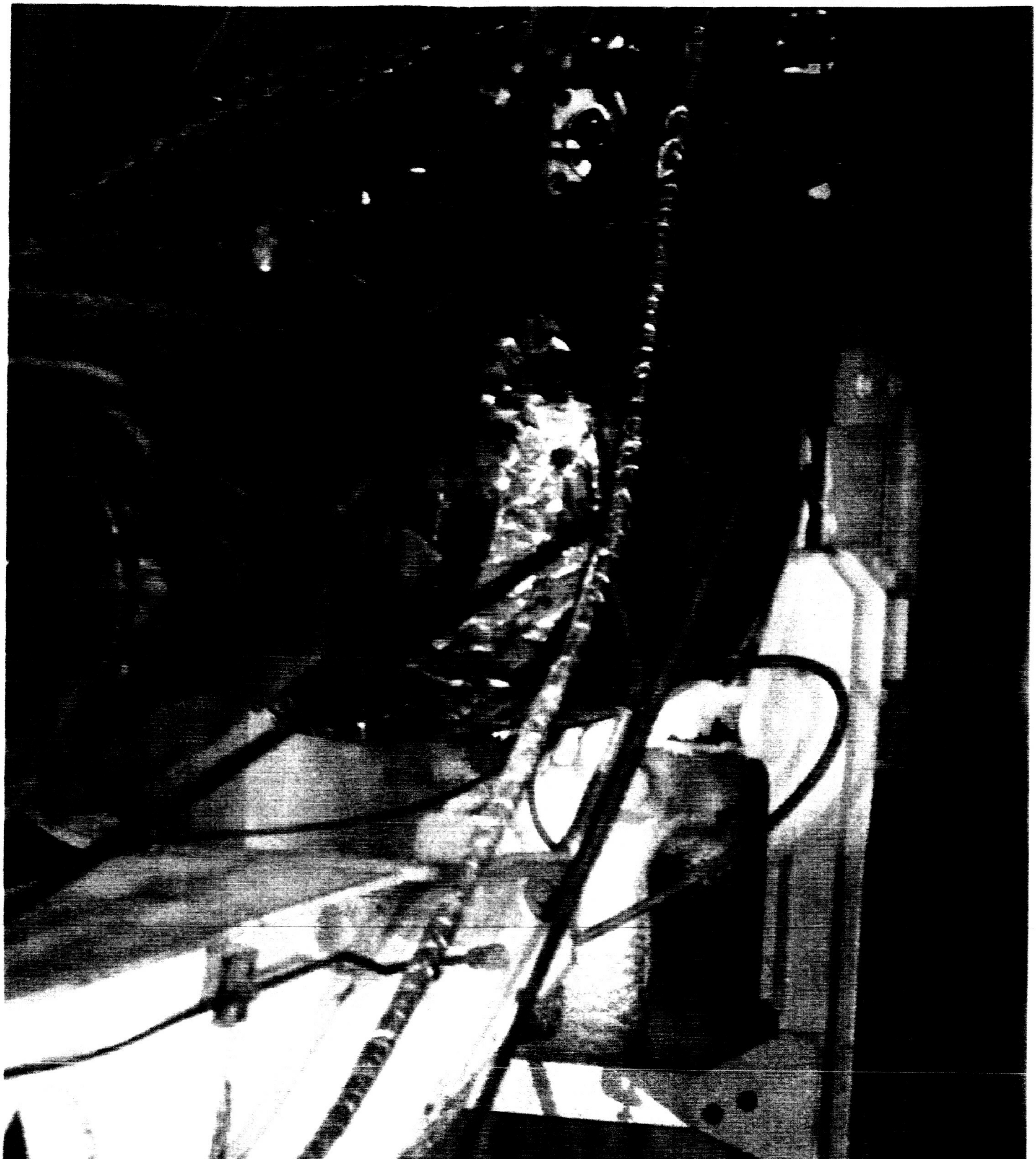
All SRB sound suppression water troughs were filled and properly configured for launch.

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The modification to the GH2 vent line prevented ice from forming but some ice/frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

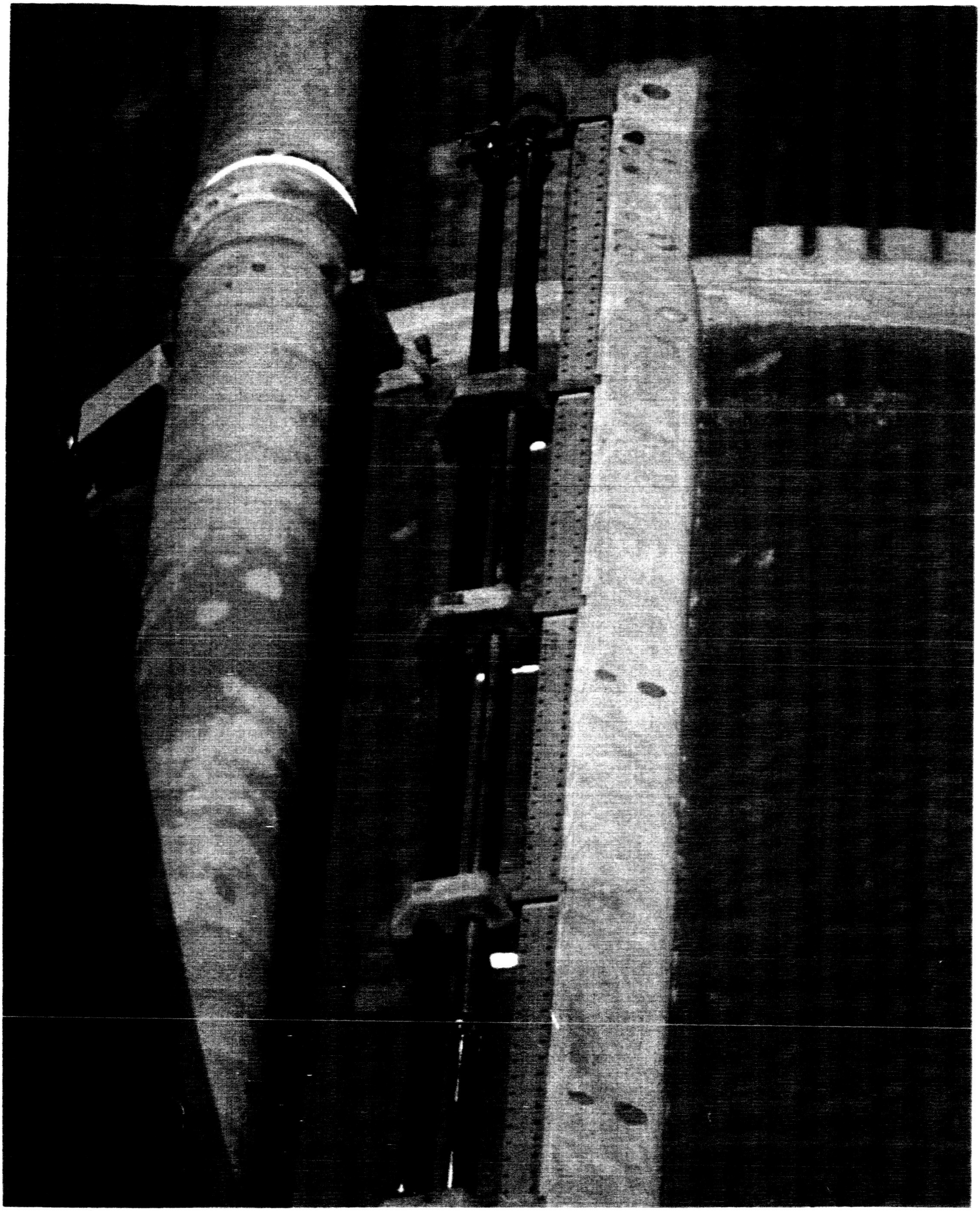
Visual and infrared observations of the GOX seals confirmed no leakage. There were no icicles on the GOX vent ducts.



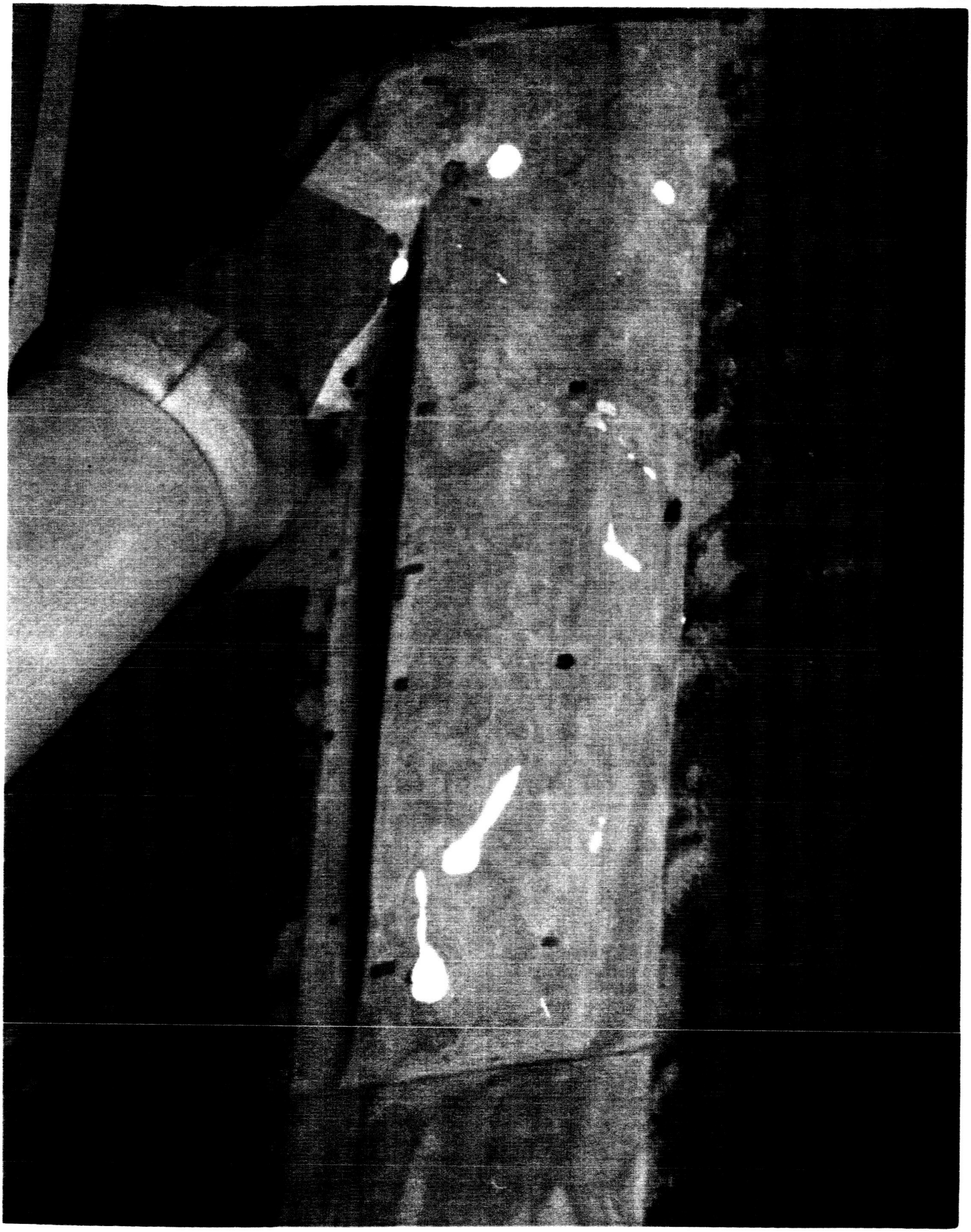
No ice/frost had formed on the LH2 tank and LO2 tank acreage. Six frost spots are visible on the +Y longeron foam closeout.



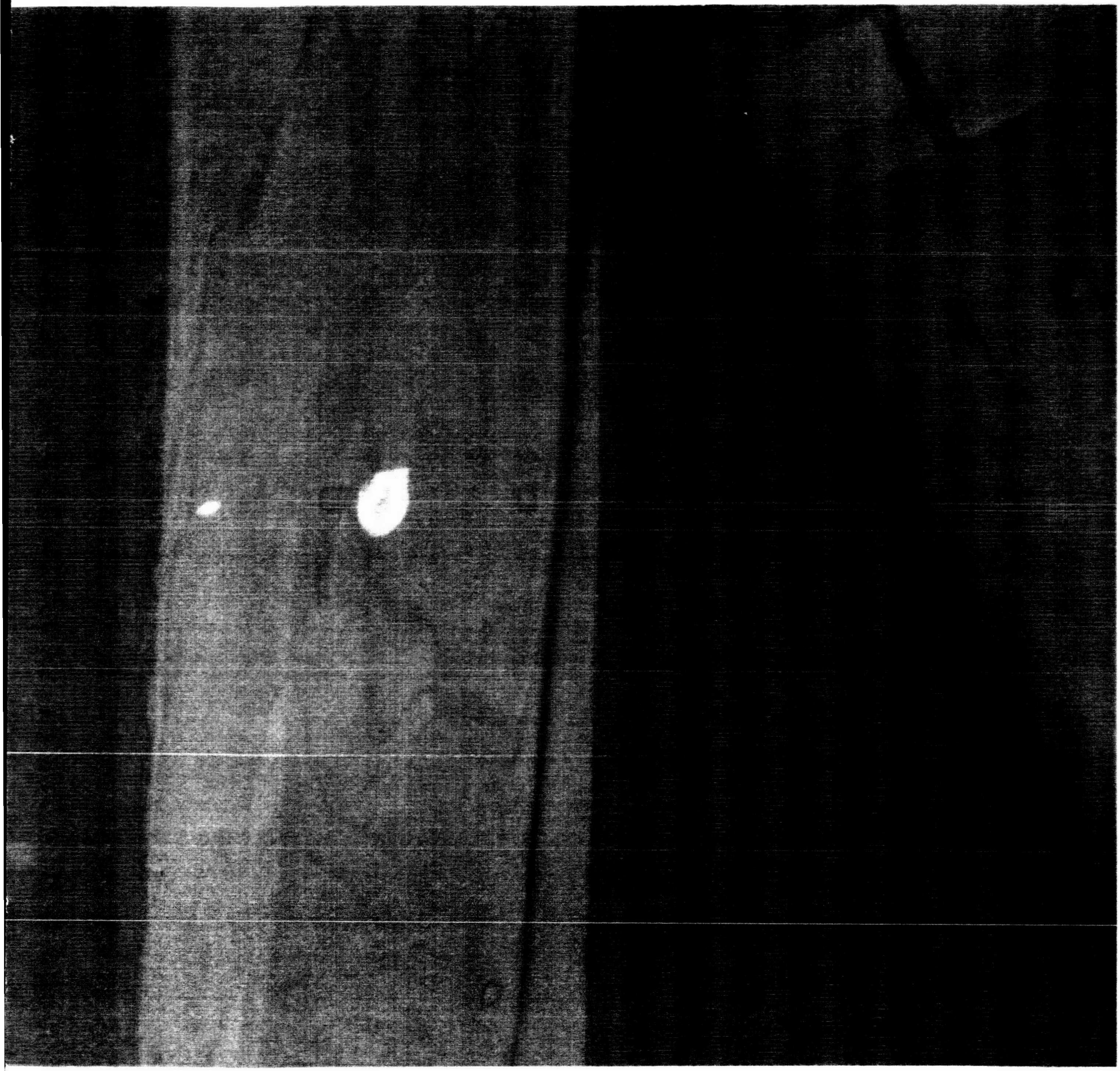
Ice/frost formations on the GUCP legs and un-insulated parts of the umbilical carrier plate were normal



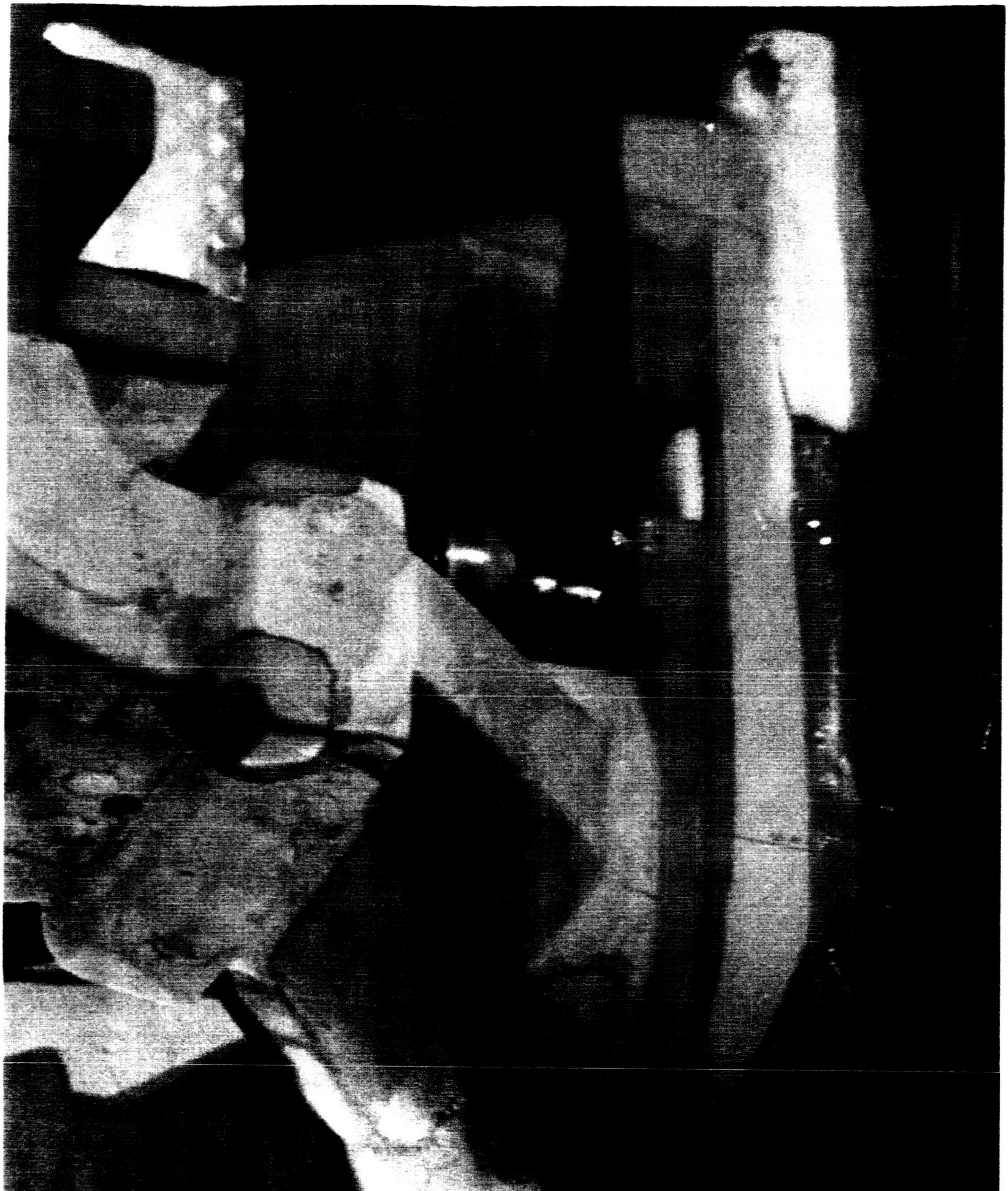
Normal amounts of ice were present in the LO2 feedline upper bellows and support brackets. Ice/frost formations along the aft edges of the pressurization line brackets was acceptable for flight per the NSTS-08303 ice criteria document.



Ice/frost formations on the +Y longeron foam closeout and in the thrust strut-to-longeron interface were acceptable for launch per NSTS-08303.

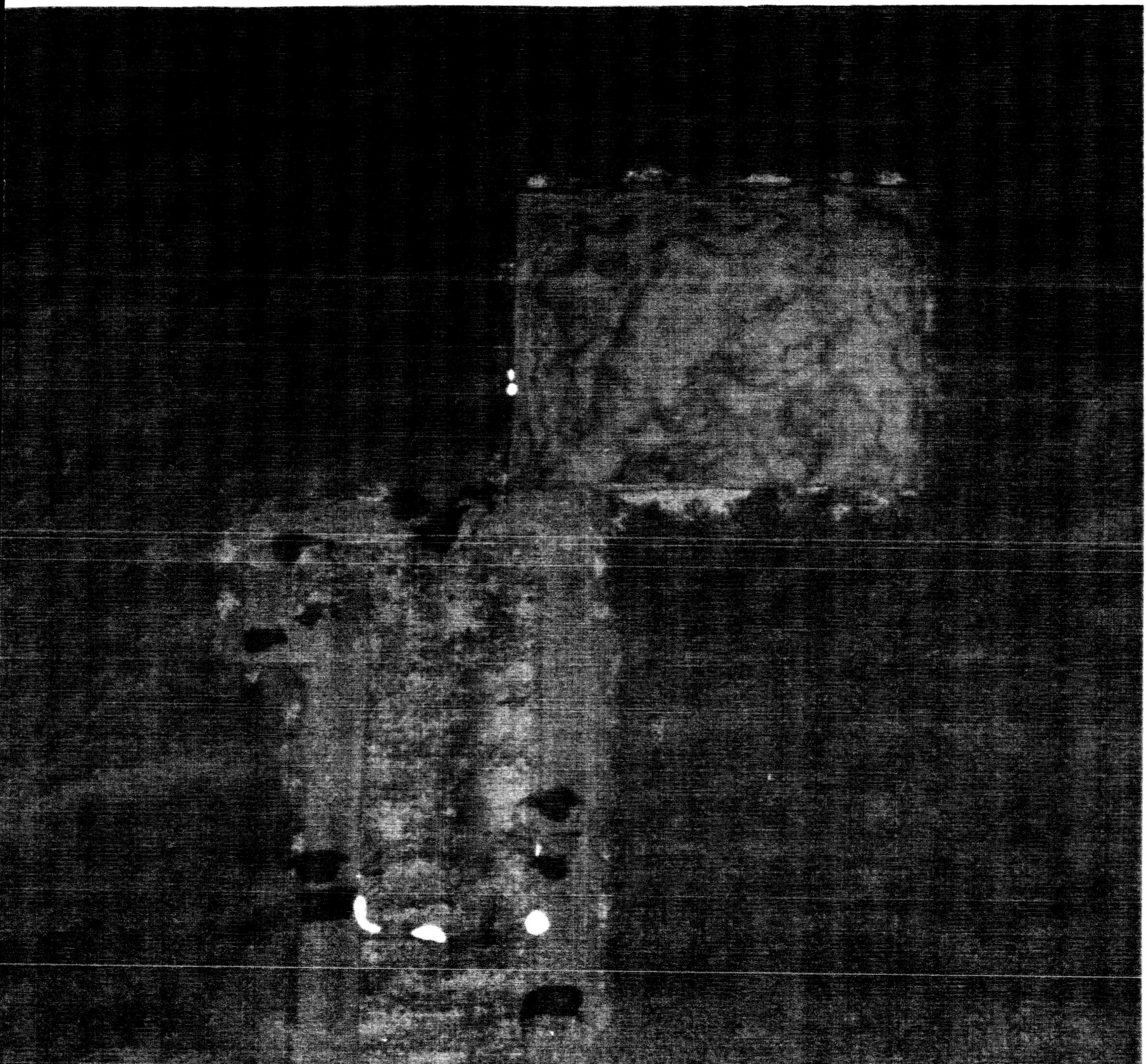


Ice/frost spots on the -Y longeron foam closeout were acceptable for launch per NSTS-08303

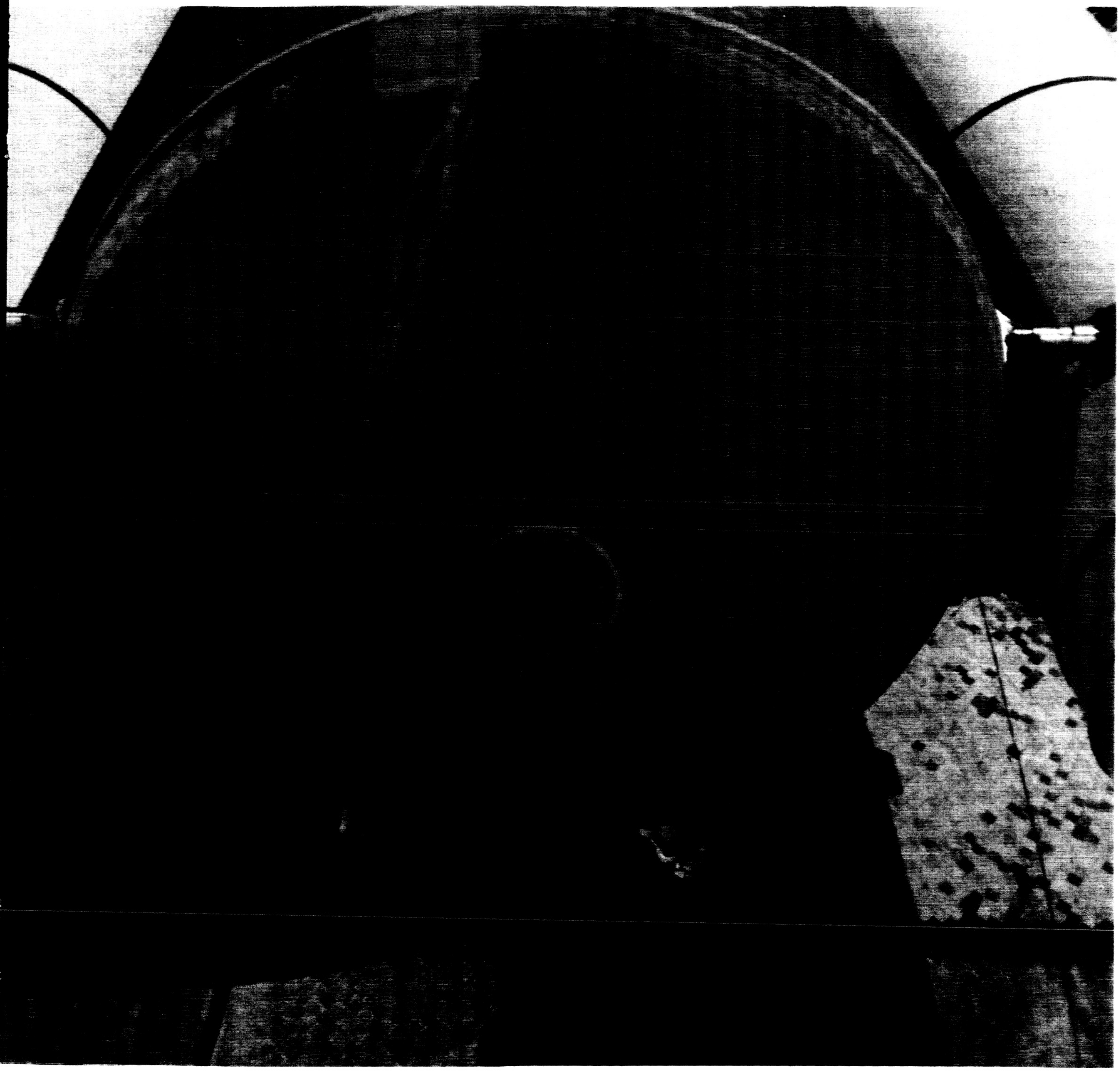


Ice/frost formation on the top/side of the LH2 umbilical/purge barrier baggie and on the forward outboard pyro canister purge vent was typical. Frost on the umbilical (near pressurization line flange) is the result of minimum thickness TPS.

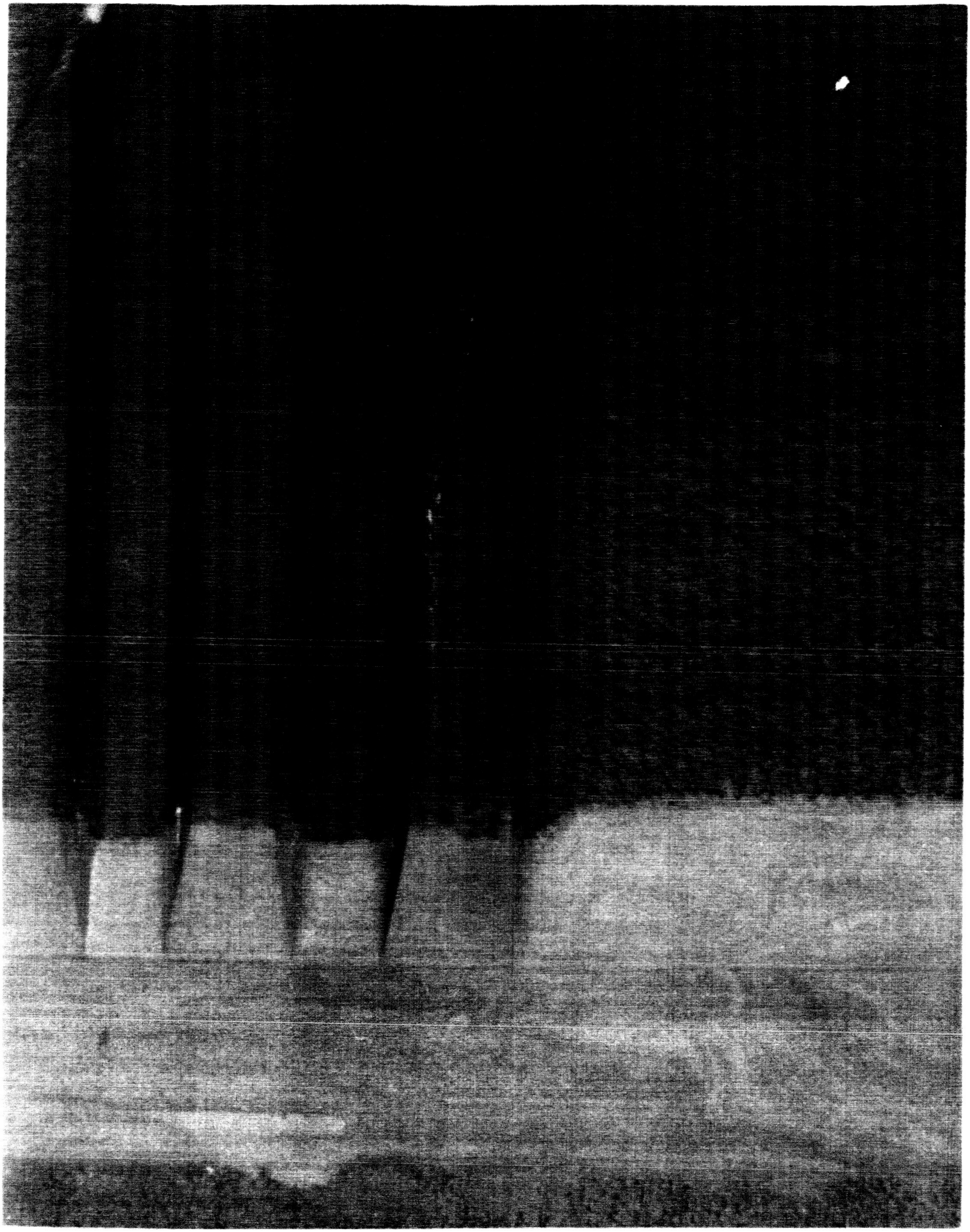
Ice/frost formation on the aft plate gap purge vent, aft pyro canister purge vent, LH2 recirculation line upper bellows, and aft side of LH2 umbilical/purge barrier baggie was typical. The 17-inch flapper valve actuator access port foam plug was properly closed out with no ice/frost on the bondline.



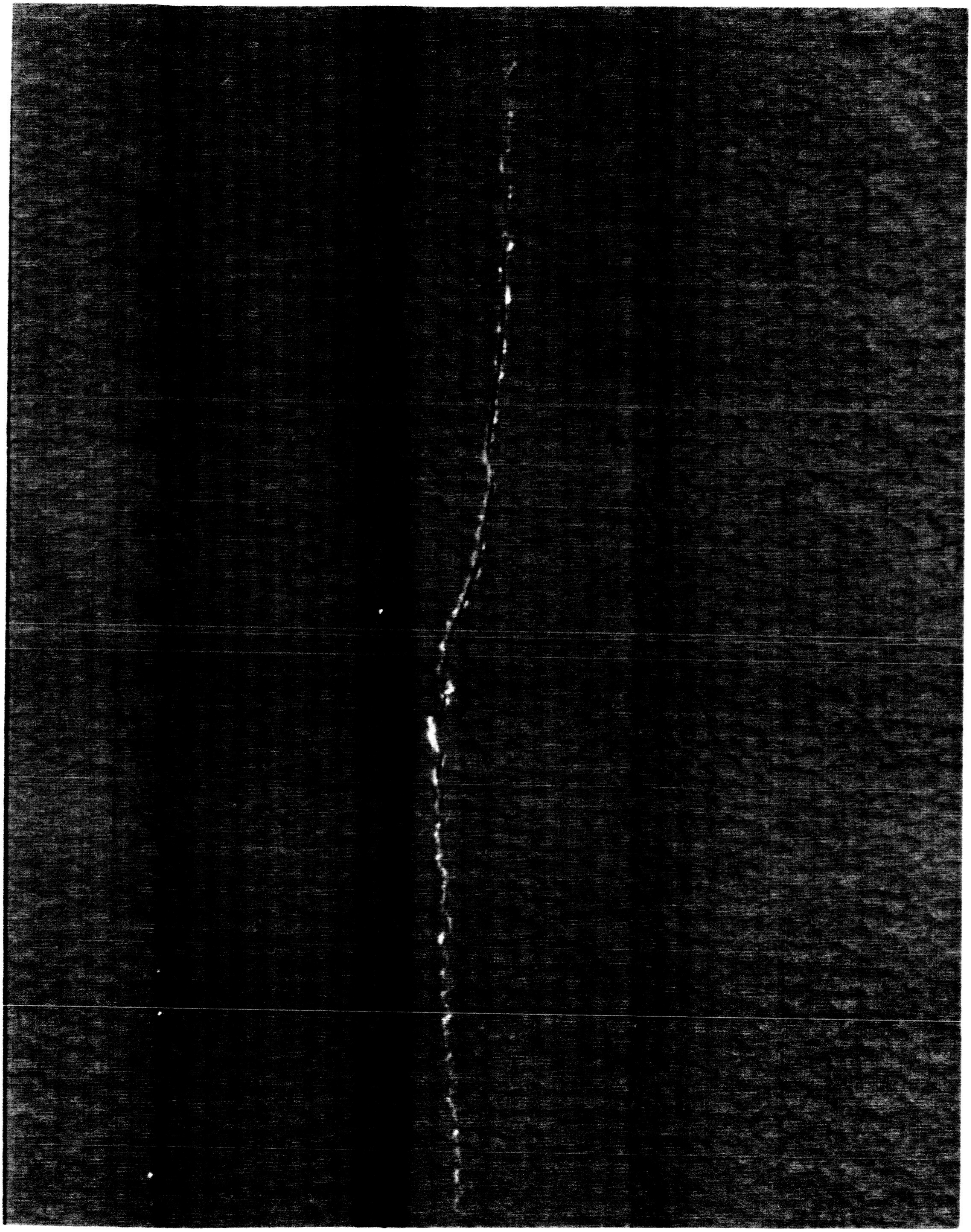
Numerous ice/frost spots appeared on the aft hardpoint closeout along the bondlines and knit lines - a condition acceptable for flight per the NSTS-08303 ice criteria.



Overall view of ET-35 LH2 tank aft dome. Light streaks mark the location of sanded foam from a spill during manufacture.



An IPR/PR was taken against a 24-30 inch TPS crack in the first stringer valley on the GUCP side of the -Y thrust panel. The condition was accepted for flight by MRB approval.



The crack was 1/4-inch wide, appeared to go to substrate, had no offset, and was not filled with ice or frost.

6.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, pad surface and pad acreage was conducted on 2 December 1990 from launch + 3-1/2 to 7 hours. No flight hardware or TPS materials were found with the exception of one Orbiter base heat shield Q-felt plug near the ESP park site. These plugs have been found on previous flights.

South SRB holddown post erosion was normal. Shim material on HDP #1, #2, and #6 was intact, but debonded to various degrees. Shim material on HDP #5 was also debonded and partially missing from two sidewalls. North holddown post doghouse blast covers were in the closed position and exhibited typical erosion. The SRB aft skirt purge lines were in place but slightly damaged. The SRB joint heater T-0 umbilicals showed typical post launch damage.

The GOX vent arm, OAA, and TSM's showed the usual minor amount of post launch damage. The GH2 vent arm appeared to have retracted nominally, was latched on the eighth tooth of the latching mechanism, and had no loose cables. However, one of two ratchet bar spring retention devices failed. The spring broke loose but remained attached to the bar. The ET intertank access structure sustained typical plume heating effects.

Emergency egress slidewire basket #3 on the FSS 195 foot level had released due to launch vibrations and was in the landing zone

A total of 5 pieces of Instafoam were recovered on the FSS. Four pieces, two of which were charred, were found on the FSS 195 foot level near the emergency egress slidewire baskets. The largest piece measured 4"x3"x2". In addition, an 8"x10"x4" curved section of scorched foam was found east of the MLP on the pad apron. The concave side exhibited the imprint of a weld line and confirmed the foam had originated from the GH2 vent line.

Two cable tray covers were missing from the FSS 215/RSS 207 foot levels. (A debris object, most likely one of these covers, was visible in video item OTV 170 moving above the OAA white room after the vehicle had cleared the tower). A 12" x 28" cover was found on the RSS 135 foot level and a 30" x 30" cover was found on the pad slope due west of the FSS. Several large covers were loose on the RSS 135 foot level. Numerous other cable tray cover fasteners on the RSS 175 foot level were also loose. (Seven cable tray covers were lost and several other covers were loose on the FSS/RSS after the STS-41 launch). The modification program to replace old cable tray cover fasteners with new trapeze fasteners is still in work at Pad 39B.

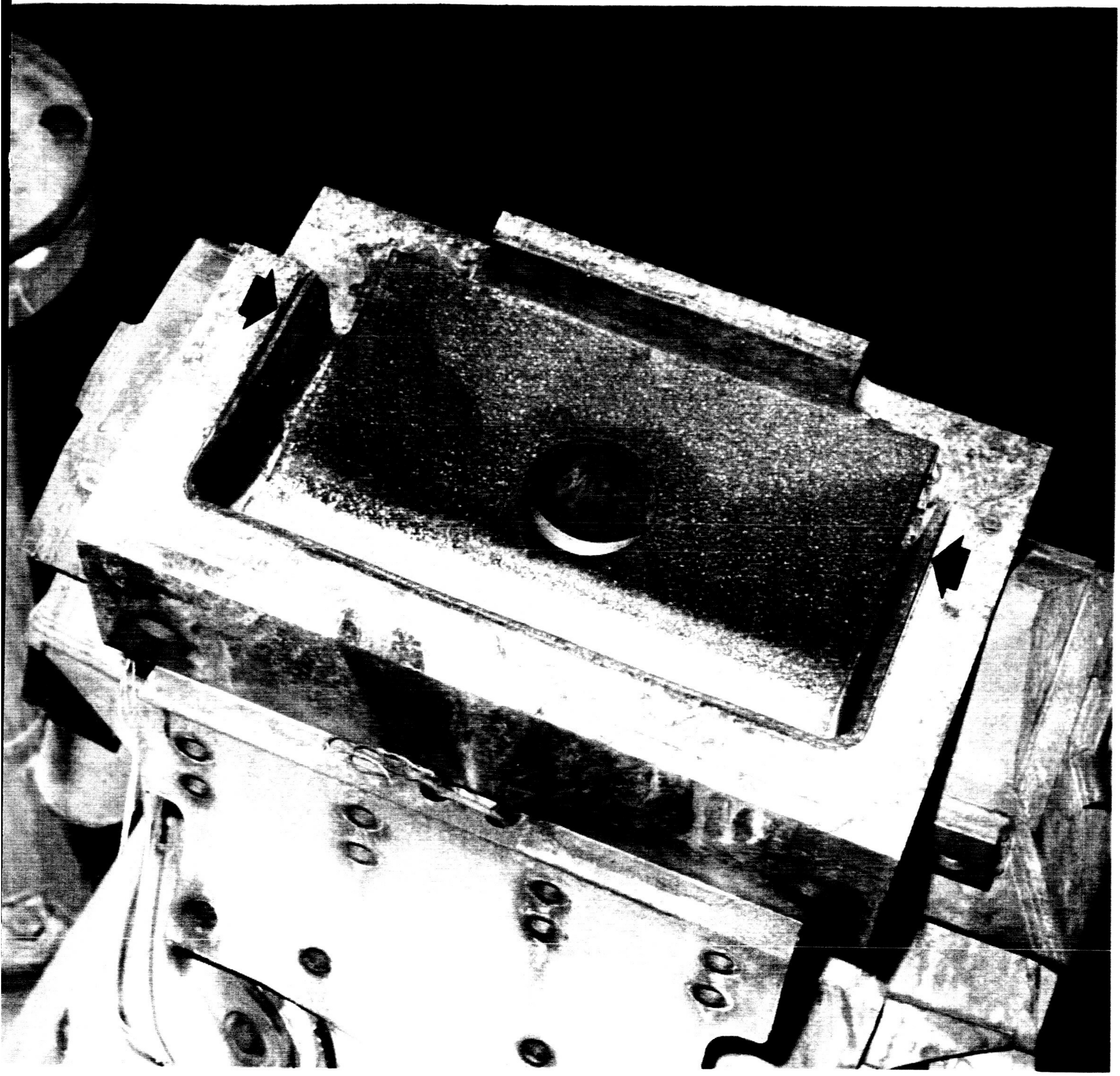
An unidentified iron box 12"x12"x8" lay on the pad slope west of the MLP. Nearby, a portion of a phenolic light reflector was found.

Inspection of the beach from UCS-10 to Complex 40, beach access road, railroad tracks, water areas around the pad, and the ocean areas under the vehicle flight path was completed on December 3, 1990. No flight hardware was found.

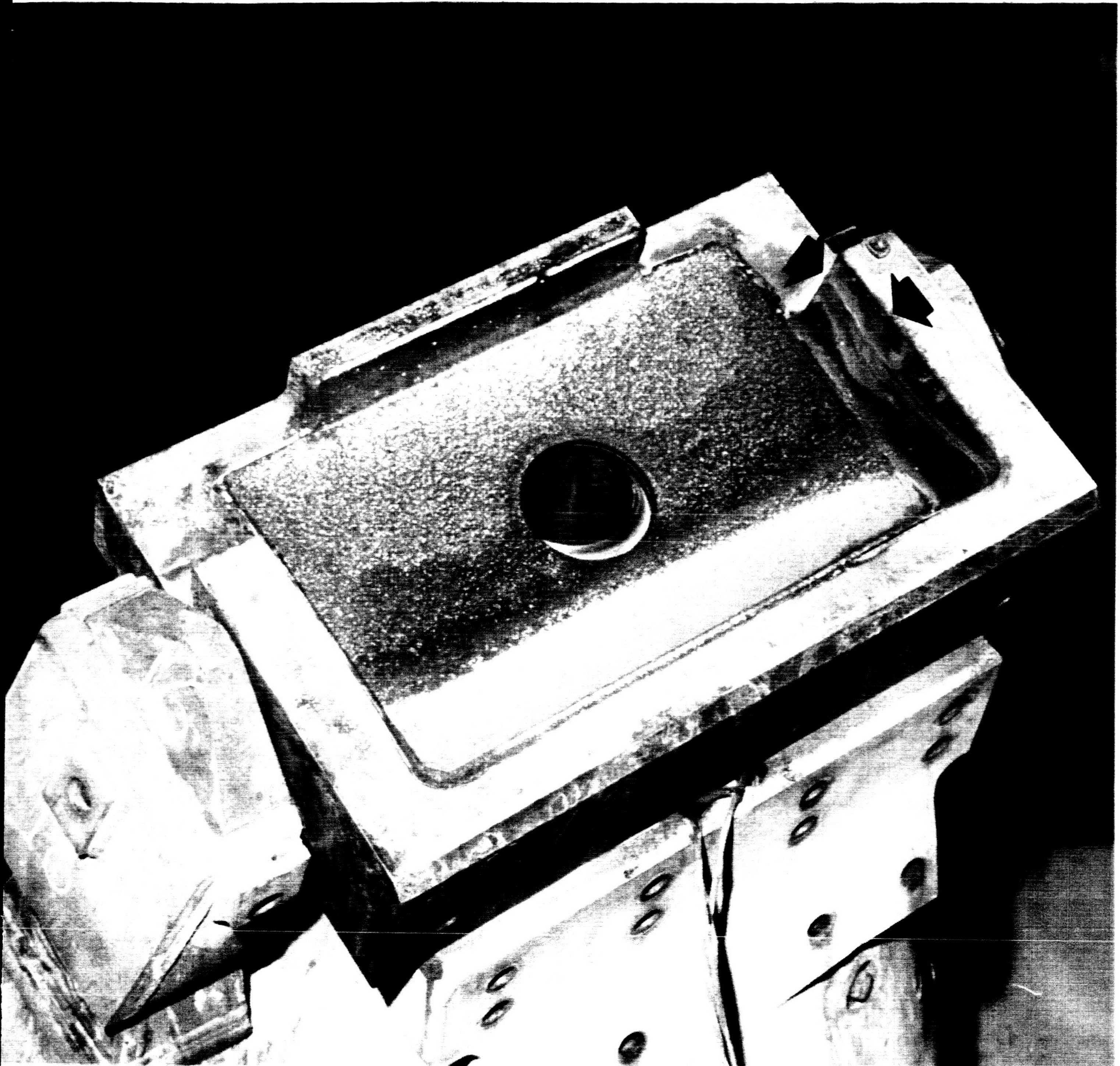
Patrick AFB and MILA radars were configured in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent but after SRB separation (due to the masking effect of the SRB exhaust plume). Although most of the signal registrations were very weak and often barely detectable, which generally compares with the types of particles detected on previous Shuttle flights, a total of 47 particles were imaged in the T+140 to 395 second time period. 30 of the particles were imaged by only one radar, 14 particles were imaged by two radars, and 3 particles were imaged by all three radars. There were no particles that stood out by echo amplitude above the others. Signal returns for the particles were in the same range that has become typical for previous missions.

Post launch pad inspection anomalies are listed in Section 11.1

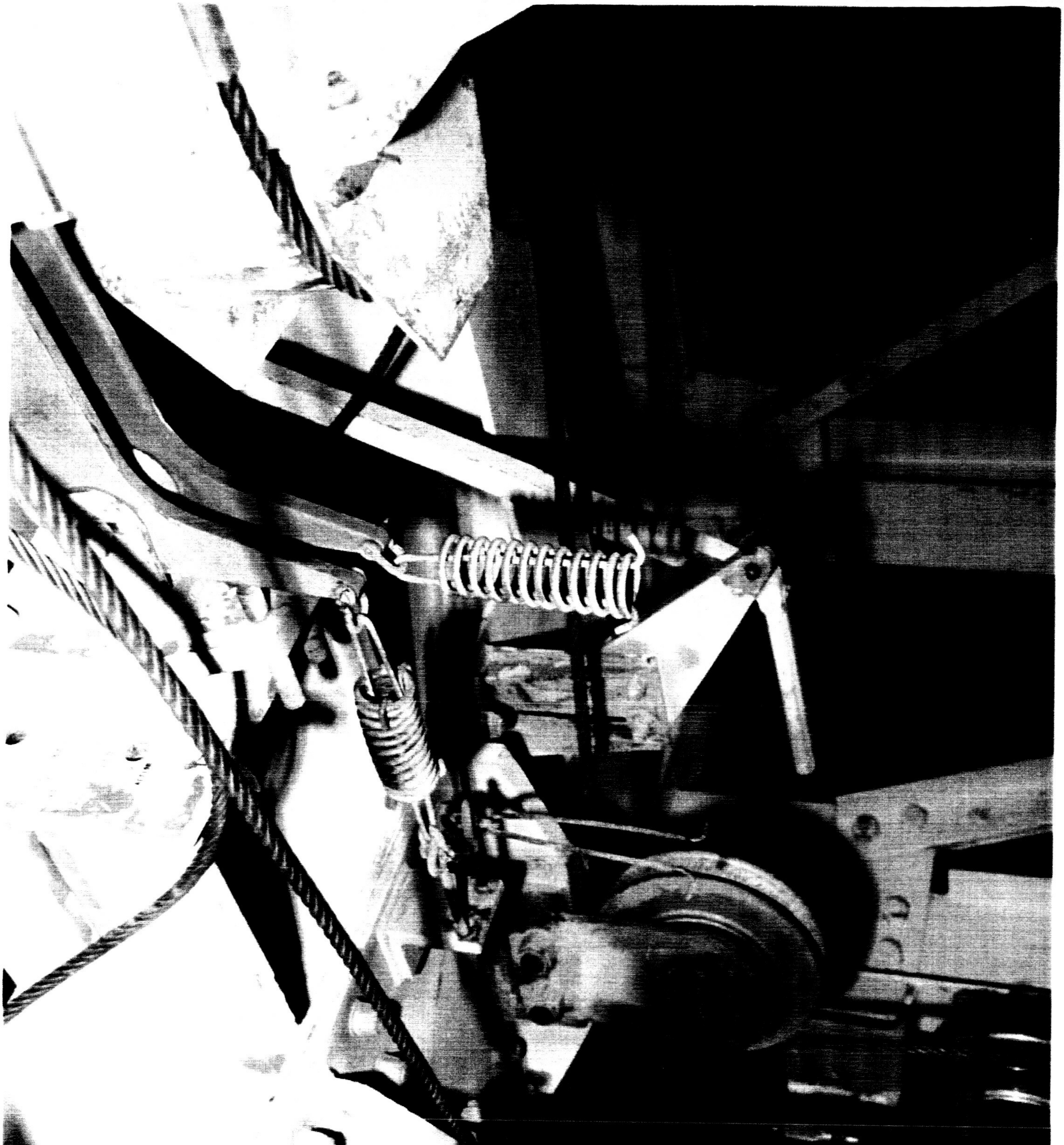
Typical post launch condition of north holddown posts. Doghouse blast covers had closed normally. Due to debris concerns, less RTV was applied to the bands around the holddown post bases.



Typical post launch condition of south holddown posts.
Sidewall shim material debonded from the shoe is an anomaly.



Two pieces of sidewall shim material, 10"x1" and 6"x0.5", were missing from holddown post #5 after launch



Although the GH2 vent arm retracted normally and latched on the eighth tooth, one of the two ratchet bar spring retention devices failed. The spring broke loose but remained attached to the bar.

Two cable tray covers were missing from the FSS 215/RSS 207 foot levels after launch. Several large covers were loose on the RSS 135 foot level.

Typical post launch debris included facility covers and light fixtures, GH2 vent line insulation, miscellaneous brackets and fasteners, facility paint scale, SRB throat plug material, and one Orbiter Q-felt plug found near the ESP park site.

7.0 FILM REVIEW SUMMARY/PROBLEM REPORT DISPOSITION

A total of 127 film and video data items, which included 37 videos, 44 16mm films, 25 35mm films, 6 70mm films, and 15 on-orbit still frames, were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission.

SSME ignition vibration/acoustics caused the loss of small pieces of tile surface coating material from tiles on the upper surface of the elevons, base heatshield, OMS nozzle base, body flap, and LH RCS stinger.

Helium purge vapors and ice build-up on the LH2 umbilical had been typical during tanking, stable replenish, and launch. There were no unusual vapors or cryogenic drops during liftoff.

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. All T-0 umbilicals separated cleanly. The GH2 vent line latched properly with no rebound. A facility debris object, most likely one of the FSS/RSS cable tray covers, was visible moving above the OAA white room after the vehicle cleared the tower OTV 170.

Three ordnance fragments, possible pieces of NSI cartridge, fell from the HDP #1 aft skirt stud hole (E-9), four ordnance fragments fell from the HDP #2 stud hole (E-8), and one fragment fell from the HDP #8 stud hole (E-14, 28) shortly after liftoff.

Numerous particles were ejected out of the SRB exhaust holes after T-0 as the vehicle attained 30 feet altitude (E-61, 62, 63, 64). Many film and video items recorded various amounts of flying debris on and around the pad after the vehicle cleared the tower. This debris is SRB throat plug material and shredded sound suppression water troughs - an expected occurrence.

Light-colored particles fell out of the SRB plume just after the roll maneuver and later in flight. Similar particles on previous flights have been attributed to either chunks of SRB propellant/inhibitor or pieces of aft skirt instafoam.

Orbiter LO2 umbilical purge barrier (baggie) separated from the vehicle and fell aft in film items E-207, 223.

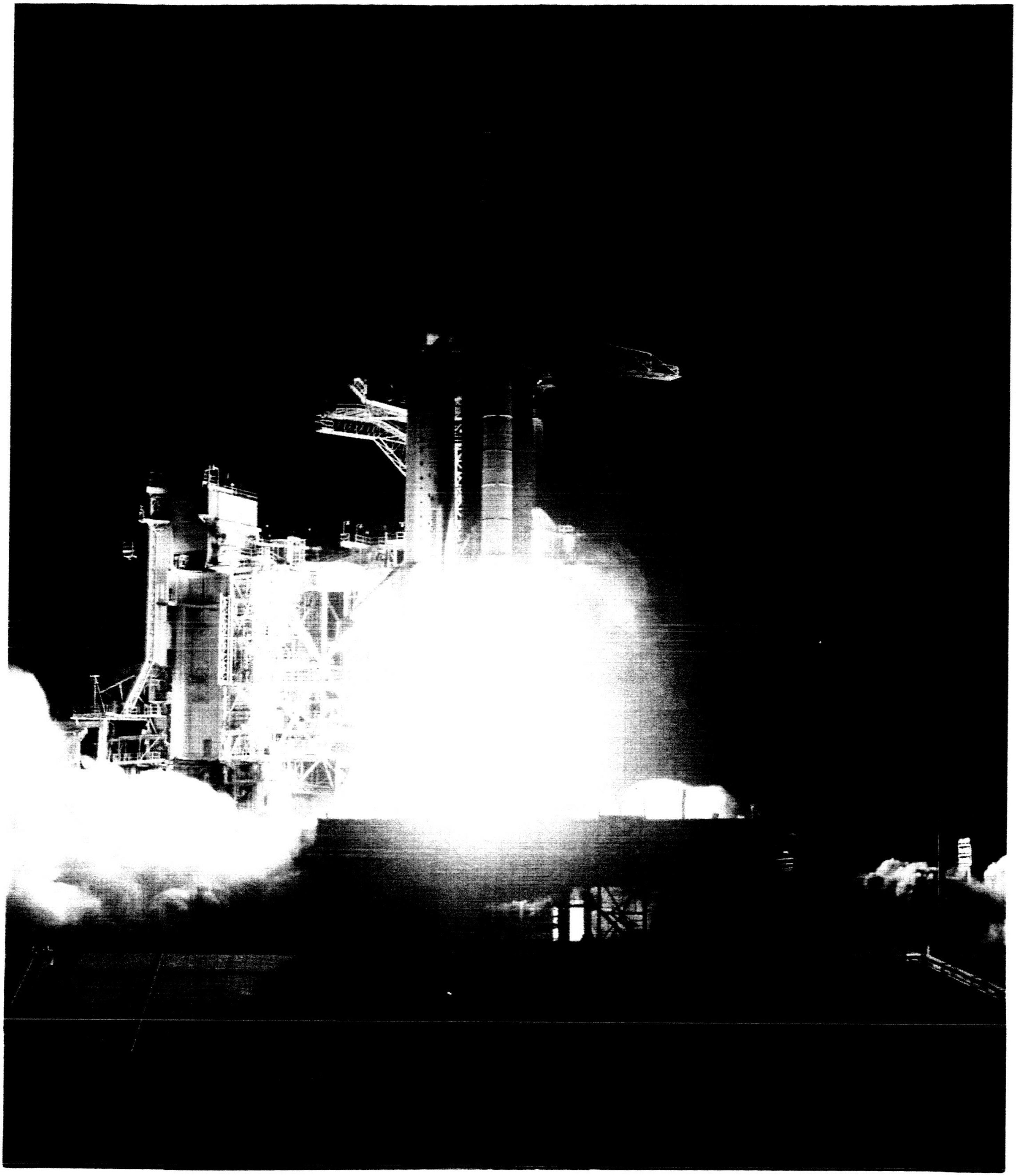
A 360-inch camera lens was substituted for the usual 180-inch lens on film item E-207 for this mission to obtain data on SRB thermal curtain performance. This change provided an excellent close-in view of the aft end of the vehicle by doubling the size of the image. A piece of thermal curtain tape came loose near the nozzle extension (frame 3414), fluttered in the air

flow near the aft ring, and fell into the SRB plume. This piece of tape was significantly different in appearance and behavior than the thermal curtain material observed on STS-38.

On-orbit photography of the External Tank after separation from the Orbiter revealed at least 12 divots on the LH2 tank-to-intertank +Z (Orbiter) side flange closeout and one divot on the upper LH2 tank acreage near the LH bipod closeout. Six of the divots had a major dimension of 8-10 inches. No other anomalies were visible on the ET. OV-102 was equipped with two 16mm and one 35mm umbilical cameras to record SRB and ET separation. The 35mm camera and one 16mm camera did not run. The remaining 16mm camera recorded SRB separation, but did not reactivate to record ET separation. Photography of the SRB separation revealed no anomalies. Crew hand-held photos again documented a light-colored, curved object with a smooth concave inner surface and rough, jagged outer surface near the aft end of the Orbiter. This object was similar to that observed during the Ulysses deployment on STS-41. The object is believed to be frozen MPS oxygen, or ice, from the SSME's.

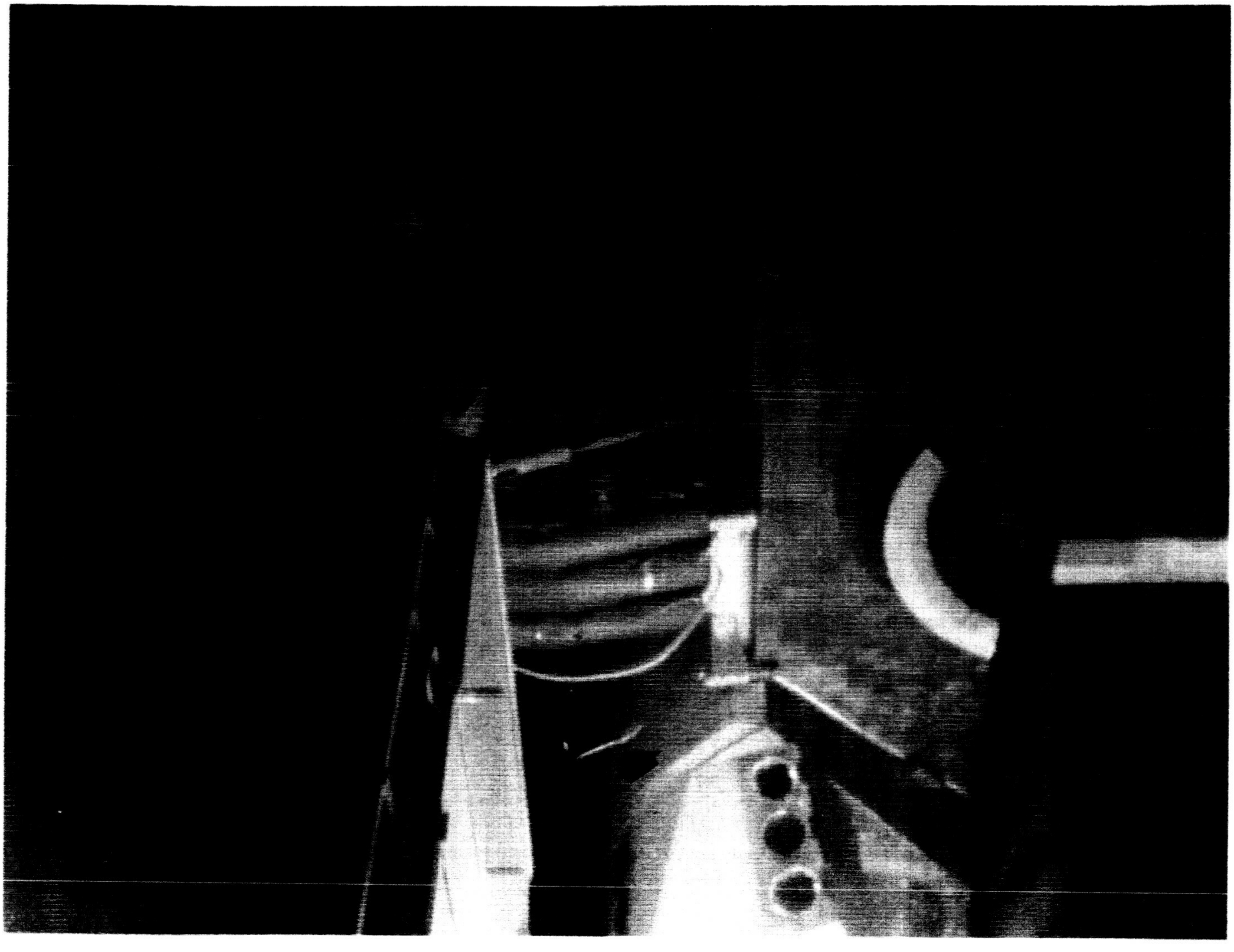
Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were nominal.

IFA's were taken against the ET LH2 tank-to-intertank flange closeout divots and the failure of the umbilical cameras. No PR's or IPR's were generated as a result of the film and video data review. Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 11.2.

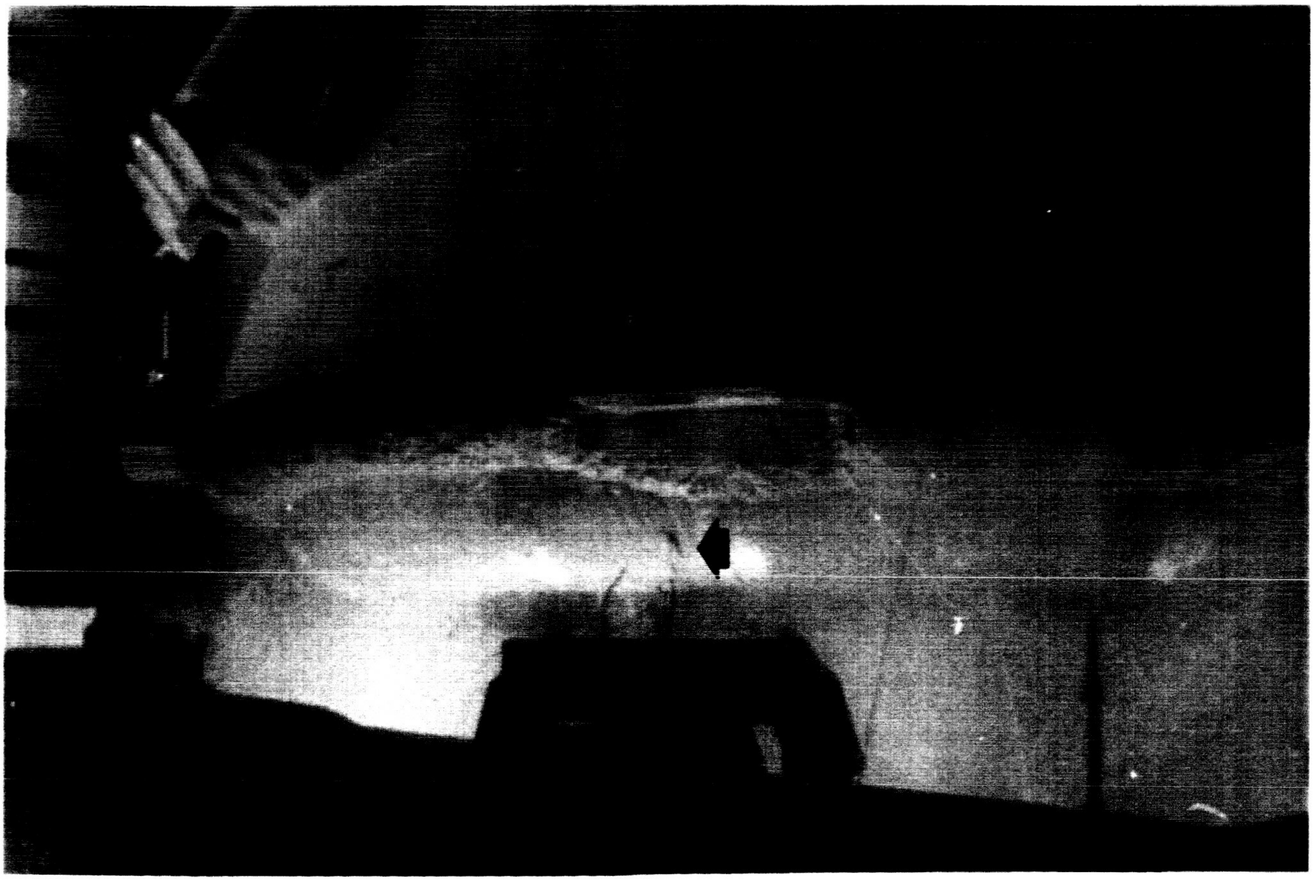


Numerous particles of SRB throat plug material were ejected out of the exhaust holes after T-0, an expected occurrence, but none trailed smoke like those observed during the STS-38 launch.

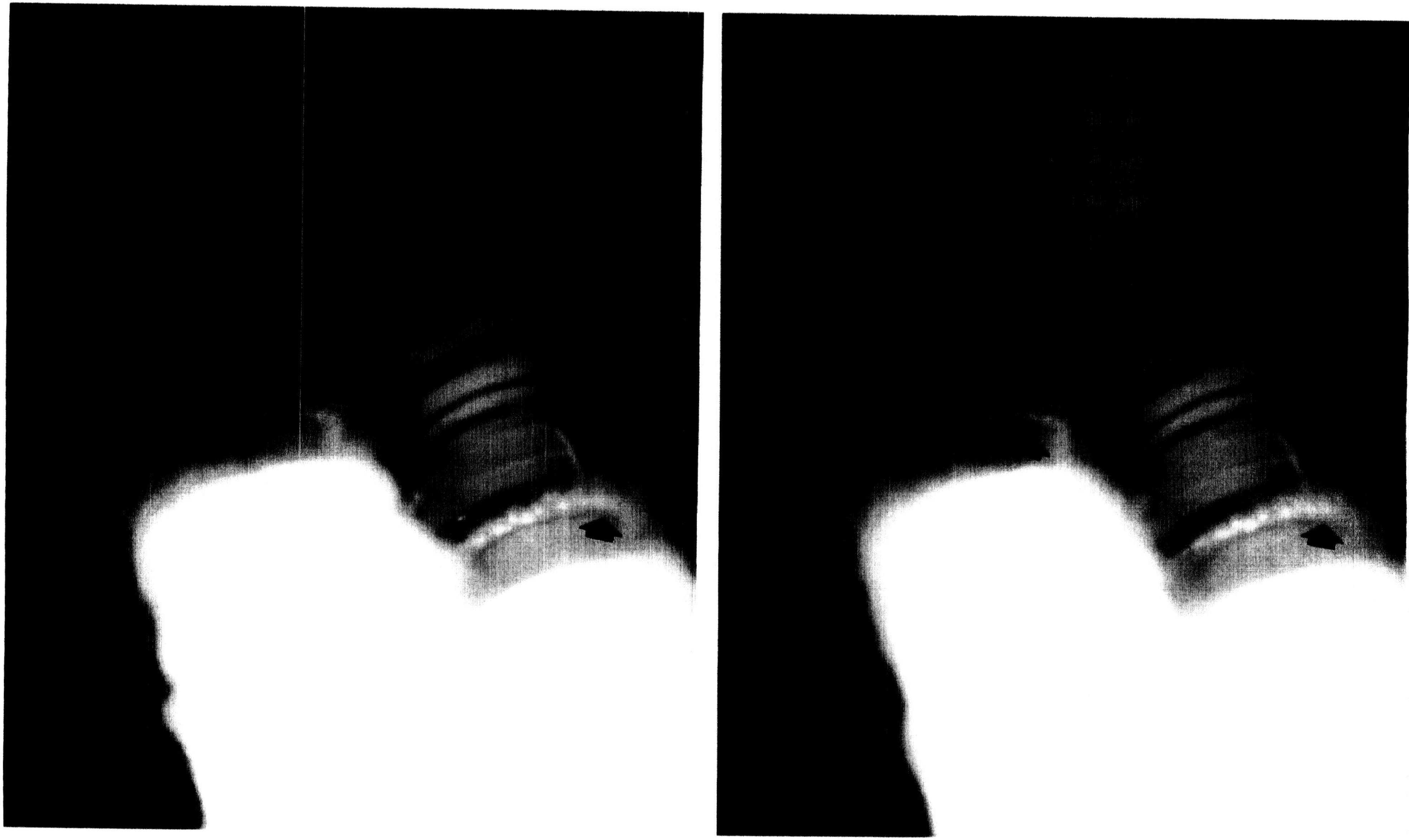
SSME ignition caused pieces of ice to shake loose from the LO2 T-0 umbilical/TSM interface. None of the ice particles contacted the Orbiter. SSME ignition vibration/acoustics also caused pieces of tile surface coating material to shake loose from the upper surface of the elevons (arrows).



A debris object, most likely a tie-wrap, fell from the LO2 TSM door just after the T-0 carrier plate began to retract

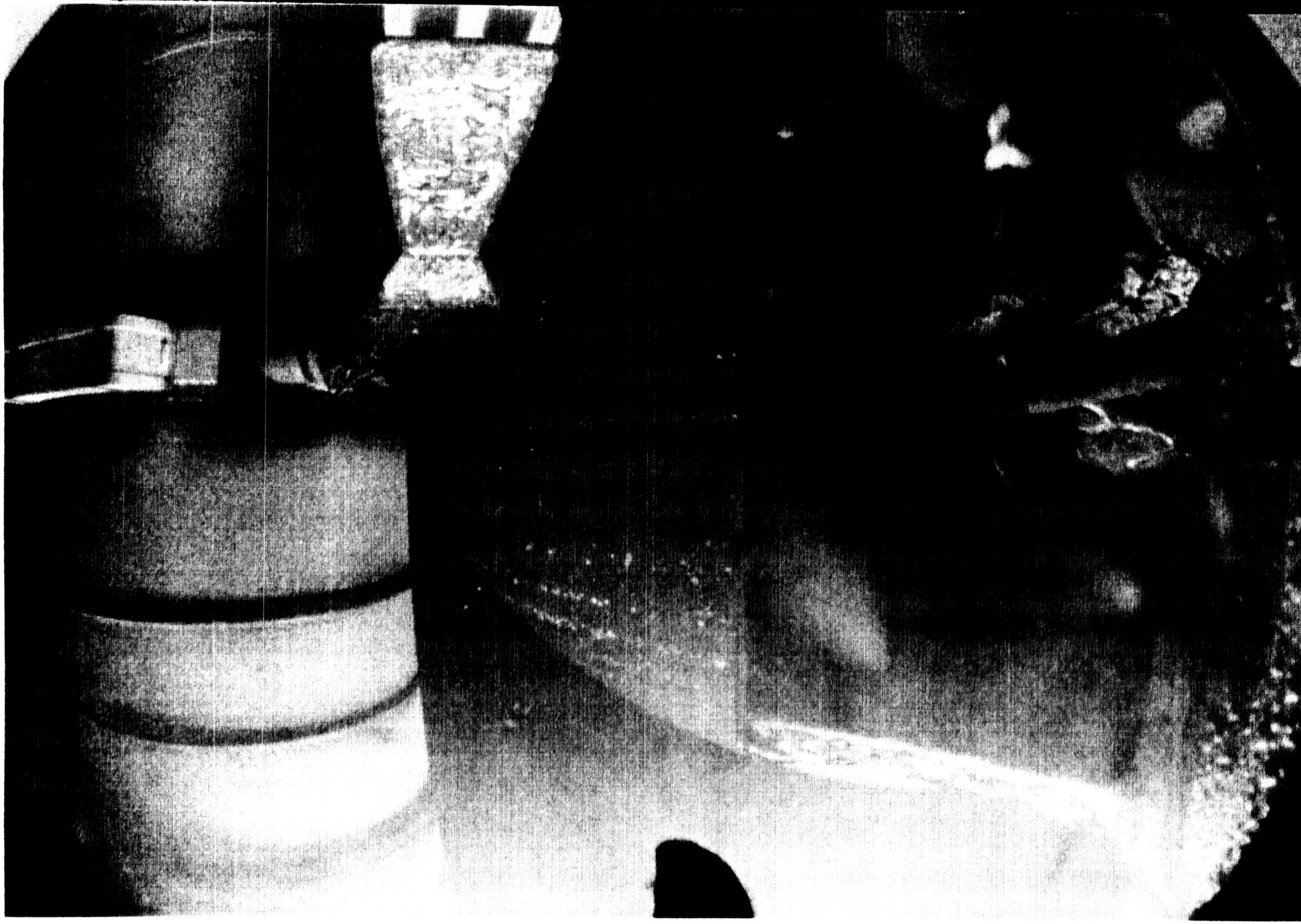


Film item E-8 recorded four ordnance fragments falling from the HDP #2 DCS and a piece of shim material/putty (arrows)

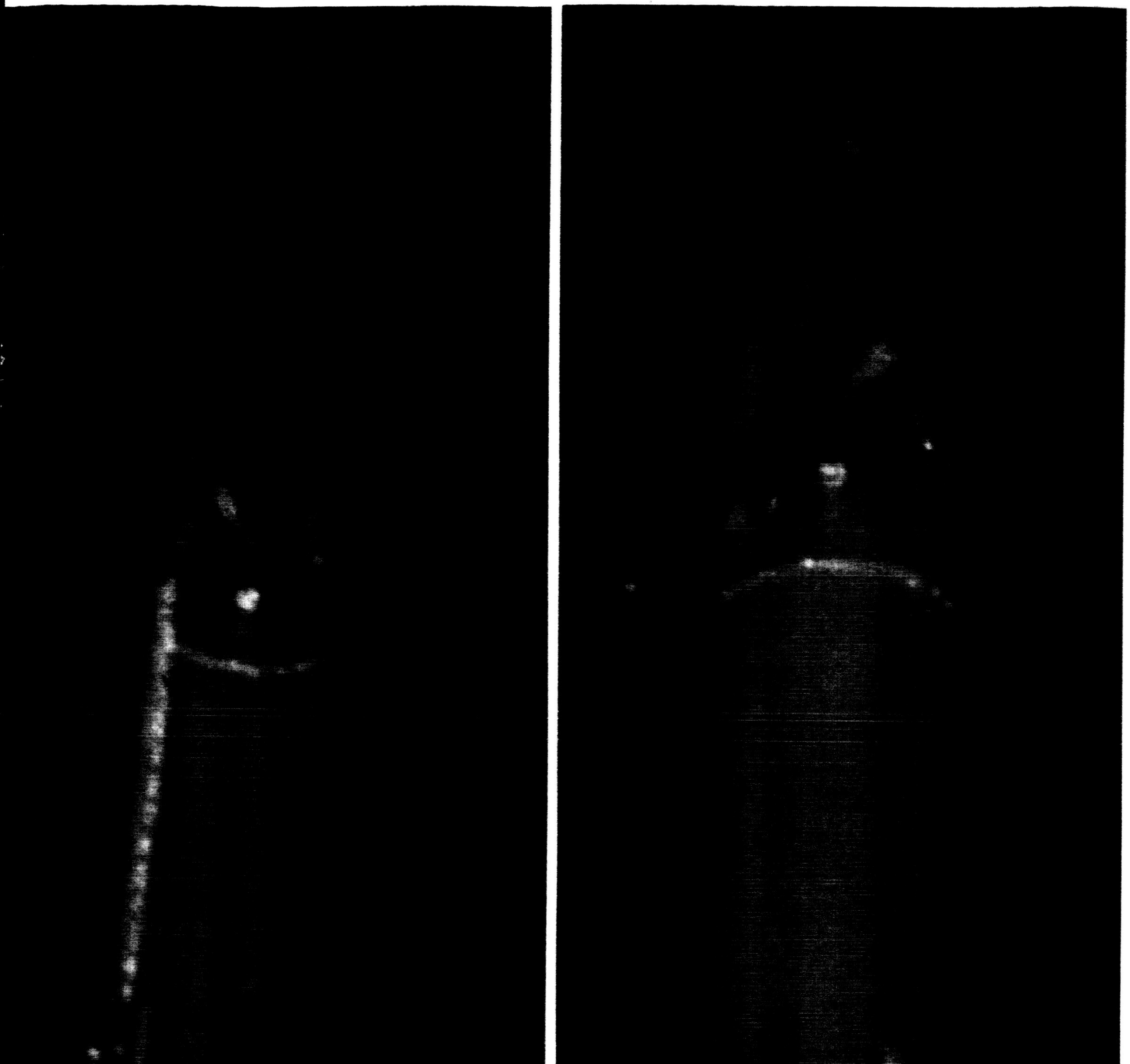


180-inch lens on UCS-10 camera was replaced with a 360-inch lens to double image size. SRB thermal curtains bulged/rippled due to aerodynamics, delta pressure, and plume recirculation effects.

Film item E-207 recorded SRB thermal curtain tape coming loose near the nozzle extension, separating from the aft skirt near HDP #7, and falling aft of the vehicle at 41 seconds MET

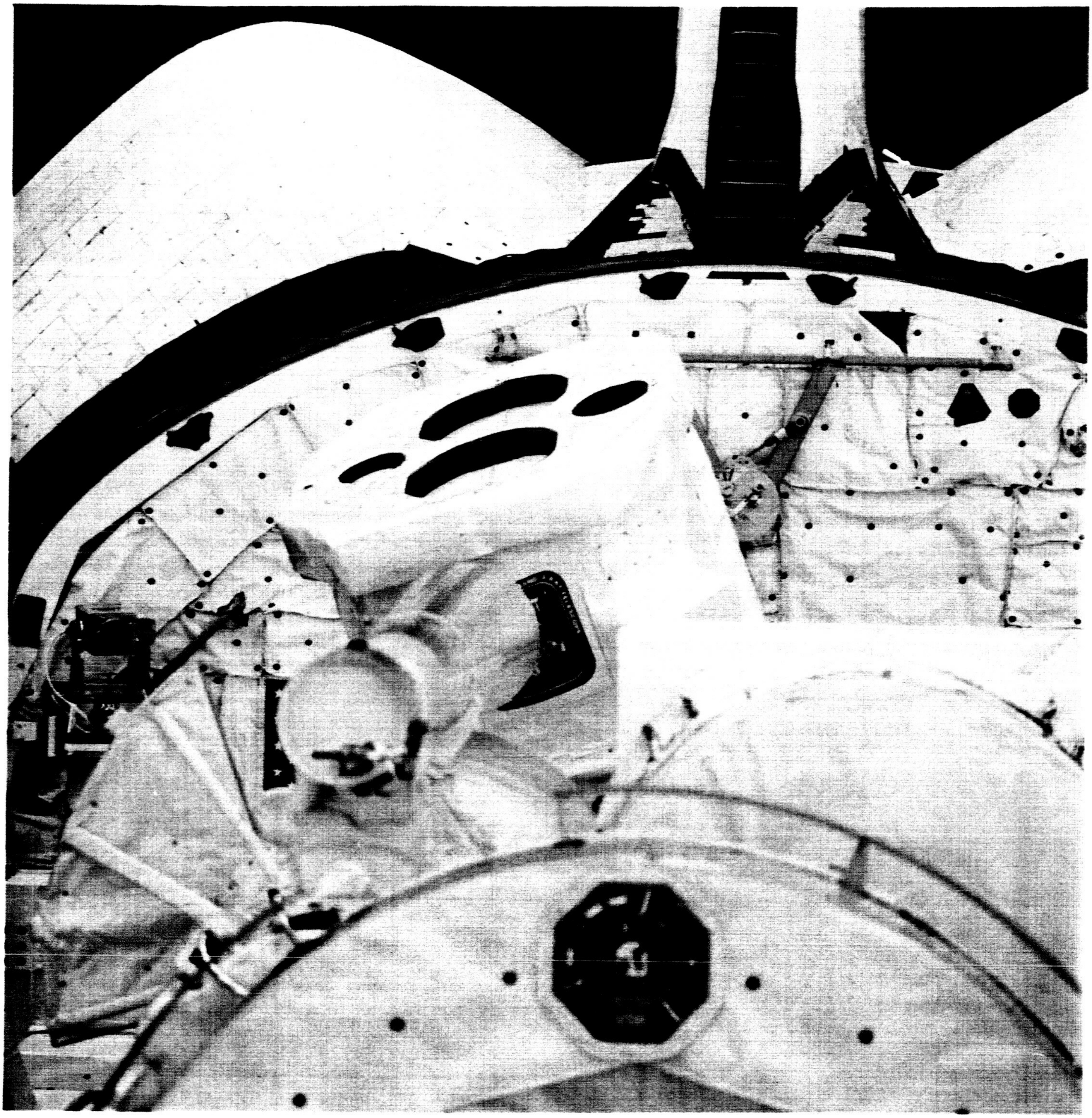


Orbiter LH2 umbilical camera recorded typical aerodynamic/thermal erosion of the TPS on the aft surfaces of the umbilical and cable trays. ET aft dome charring was caused by plume recirculation.



On-orbits photos of the External Tank after separation revealed at least 12 divots on the LH2 tank-to-intertank flange and one divot on the upper LH2 tank acreage near the LH bipod closeout.

Light-colored object floating in vicinity of Orbiter vertical stabilizer has smooth concave inner surface and rough, jagged outer surface. This object could be frozen MPS oxygen, or ice, that had adhered to a smooth curved surface, such as the SSME nozzles.



View from Orbiter aft flight deck windows shows edge of SSME #1 between vertical stabilizer and LH OMS pod. A light-colored, jagged object appears to adhere to the exit plane of the SSME nozzle and is believed to be ice or frozen MPS oxygen.

ORIGINAL PAGE
COLOR PHOTOGRAPH

7.1 LAUNCH FILM AND VIDEO DATA REVIEW

FILM ITEMS

EX1 400 FPS 16mm	Camera is located on MLP deck south of RH SRB exhaust duct and looks north to view SRB Heater Umbilical during ignition and liftoff.

Comments: Deleted for this mission due to lighting conditions.

EX2 400 FPS 16mm	Camera is located on the MLP deck west of RH SRB flame duct and looks east to view SRB Heater Umbilical during ignition and liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Umbilical disconnect appeared nominal. Several pieces of SRB throat plug material were ejected out of SRB exhaust hole at T-0.

EX3 400 FPS 16mm	Camera is located on the MLP deck east of LH SRB flame duct and looks west to view SRB Heater Umbilical during ignition and liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Small ice particle fell and landed on MLP deck in FOV at SSME ignition. Umbilical disconnect appeared nominal. A dark object approximately 2" x 0.5" fell from the electrical umbilical connectors on the SRB half of the umbilical. Several pieces of Instafoam and throat plug material were visible after T-0.

EX4 400 FPS 16mm	Camera is located on MLP deck south of LH SRB flame duct and looks north to view LH SRB Heater Umbilical during ignition and liftoff.

Comments: Deleted for this mission due to lighting conditions.

E-1
400 FPS
16mm

Camera is located on the NE corner of the MLP deck and views the lower ET, SRB's, and Orbiter.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SSME ignition nominal. At frame 5161 a particle moved SE away from SSV and numerous particles of throat plug material were ejected out of SRB exhaust hole after vehicle cleared FOV.

E-2
400 FPS
16mm

Camera is located on the SE corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SSME ignition nominal. LH2 TSM door closure was normal. SRB stiffener ring foam outgassed. Throat plug material was ejected out of SRB exhaust hole after vehicle cleared FOV.

E-3
400 FPS
16mm

Camera is located on the SW corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SSME ignition nominal. Aft RCS paper covers were torn loose and pulled into SSME plume causing orange streaks. FSS water was activated properly. LO2 TSM door rebounded slightly before closing. A particle moved to the left behind the LH2 TSM after vehicle had cleared the TSM. Bright particles were ejected out of SSME exhaust hole headed west toward FSS.

E-4
400 FPS
16mm

Camera is located on the NW corner of the MLP deck and views lower ET, SRB's, and Orbiter.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SSME ignition nominal. Ice particles fell from ET/ORB umbilicals at SSME ignition and T-0. Ice particles, possibly from EB-5 and EB-6, fell without contacting the vehicle. Numerous pieces of water trough and throat plug material were ejected out of SRB exhaust hole at T-0.

E-5
400 FPS
16mm

Camera is located on the east side of the MLP deck and views the Orbiter RH wing, body flap, and lower ET/SRB.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals at SSME ignition, but did not contact the vehicle. SSME ignition nominal. SRB stiffener ring foam outgassed. A piece of paper entered FOV from behind TSM and fluttered around SSME #3 nozzle base prior to entering plume (frame 4094).

E-6
200 FPS
16mm

Camera is located on the east side of the MLP deck and views the RH lower Orbiter wing, body flap, ET lower LOX feedline, and ET/Orbiter umbilical area.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from LH2 ET/ORB umbilical during SSME ignition. RCS paper cover fluttered near SSME #3 nozzle interface during ascent. One particle originated in +Y area and traveled aft with no vehicle impact.

E-7
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northeast holddown post (HDP #4).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: A piece of shim material detached from HDP #4 foot area (frame 4393). Typical quantities of SRB sound suppression water trough material and throat plug material were in FOV. SRB holddown post blast covers closed properly.

E-8
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southeast holddown post (HDP #2).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Numerous particles were ejected from SRB exhaust hole after T-0. Four ordnance fragments fell from HDP #2 aft skirt Debris Containment System/stud hole. One piece of HDP shim material detached between SRB aft skirt foot and HDP #2 shoe.

E-9
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southwest holddown post (HDP #1).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals. A debris particle from behind DCS came into view after engine ignition. Three small ordnance fragments fell from HDP #1 aft skirt DCS/stud hole at frames 3834, 3855, and 3881. Two particles, either sliver of shim material or NSI cartridge debris fell from upper surface of HDP shoe. Several pieces of throat plug material were ejected out of SRB exhaust hole at T-0. Two larger pieces of foam crossed FOV as vehicle rose.

E-10
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northwest holddown post (HDP #3).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Typical quantities of water trough and throat plug material were ejected out of SRB exhaust hole at T-0. A small particle, possible shim material/putty, fell from the HDP shoe. Holddown post blast covers closed nominally.

E-11
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northeast holddown post (HDP #7).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Typical quantities of water trough and throat plug material were ejected out of SRB exhaust hole at T-0. A piece of shim material, or grounding cable, protruded on the inboard side of the HDP #7 shoe. Holddown post blast covers closure was nominal. No debris fell from the aft skirt stud hole. Facility debris passed through FOV well after vehicle has cleared pad.

E-12
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southeast holddown post (HDP #5).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Numerous particles from holddown post area were pulled into SSME plume by aspiration. Ice particles fell from the ET/ORB umbilicals during SSME ignition and landed on the MLP deck in camera foreground. Two particles moved from right to left beneath aft skirt foot. Numerous pieces of SRB throat plug material were ejected upward out of SRB exhaust hole at T-0, but most were pulled back in by aspiration. Dark vertical object on south side of HDP shoe is the grounding strap. A piece of firing cable tape flapped in the air flow as the vehicle ascended. A particle of unknown origin, most likely throat plug material, appeared between the aft skirt foot and and the HDP shoe.

E-13
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southwest holddown post (HDP #6).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Numerous particles of water trough and throat plug material were ejected out of SRB exhaust after SRB ignition.

E-14
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northwest holddown post (HDP #8).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Typical quantities of water trough and throat plug material were ejected out of SRB exhaust hole after T-0. One ordnance fragment fell from aft skirt bolt hole/DCS. Holddown post shim material protruded up from shoe. HDP blast covers closure was nominal.

E-15
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB skirt, sound suppression water troughs, and RH lower Orbiter body flap.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SSME #3 ignition nominal. Ice particles fell from LO2 umbilical. RCS paper covers were torn loose and pulled into SSME plume by aspiration. HDP blast covers closure nominal. Throat plug material was ejected out of SRB exhaust hole at T-0.

E-16
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB skirt, sound suppression water troughs, and LH lower Orbiter body flap.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell during SSME ignition. SSME ignition nominal. HDP blast covers closure was nominal. SRB sound suppression water trough material appeared after vehicle clears FOV.

E-17
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LO2 T-0 Umbilical and TSM.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen was blown west and up to LH OMS nozzle. Aft RCS paper covers were torn loose and pulled into SSME plume. Ice fell from LO2 T-0 umbilical at SSME ignition and T-0. A tie-wrap fell out of LH2 TSM door at T-0 frame 91-51 but did not contact the vehicle. Less than usual residual vapors emanated from the T-0 umbilical. Typical body flap motion occured at SSME ignition. Numerous pieces of tile surface coating material were shaken loose from elevons by SSME ignition. T-0 umbilical separation and retraction nominal.

E-18
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LH2 T-0 umbilical and TSM.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen was blown west. Ice particles fell from TSM lines and ET/ORB umbilicals during SSME ignition. SSME ignition caused a piece of tile surface coating material to shake loose from the base heatshield near SSME #2. Vapors, possibly frost subliming from cold freon supply lines, appeared after SSME ignition and were drawn downward by aspiration. Residual vapors were visible from T-0 umbilical after disconnect. Aft RCS paper covers were torn loose and pulled into SSME plume. Numerous particles moved from top right to lower left after T-0, probably throat plug material. What appears to be a tie-wrap entered FOV at frame 3605, but did not contact the vehicle.

E-19
400 FPS
16mm

Camera is located on the SE side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen was blown west and up to LH OMS nozzle. Aft RCS paper covers were torn loose and pulled into SSME plume but did not contact the vehicle. Ice fell from LO2 T-0 umbilical at SSME ignition and T-0. A tie-wrap from LH2 TSM was pulled into SSME plume. Less than usual residual vapors emanated from the LO2 T-0 disconnect. Numerous pieces of tile surface coating material were shaken loose from the upper surface of the elevons. SSME ignition acoustics/vibration caused small pieces of

tile surface coating material to fall from base heat shield tiles at two locations. T-0 umbilical separation and retraction was nominal.

E-20
400 FPS
16mm

Camera is located on the SW side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SSME ignition nominal. Residual vapors emanated from LH2 TSM T-0 umbilical plate after disconnect. LO2 TSM door rebounded once prior to closure. Aft RCS paper covers were torn loose and pulled into plume by aspiration. Ice particles fell from ET/ORB umbilicals behind body flap. SSME ignition caused pieces of tile surface coating to fall from upper surface of body flap, one adjacent to SSME #2 and a second between SSME #2 and #3.

E-21
200 FPS
16mm

Camera is located inside the LO2 TSM and views the disconnection of the T-0 umbilical.

Comments: Camera malfunction - no data.

E-22
200 FPS
16mm

Camera is located inside the LH2 TSM and views the disconnection of the T-0 umbilical.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Debris particles were visible inside the TSM at SSME ignition and T-0. Ice particles fell from T-0 disconnect at separation. T-0 umbilical separation and retraction appeared nominal. LH2 TSM door rebounded once before closure.

E-23
400 FPS
16mm

Camera is located on the MLP deck and views the RH OMS engine nozzle.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice/frost particles fell from ET/ORB umbilicals. OMS nozzle moved slightly during SSME ignition. Aft RCS paper covers were torn loose and pulled into the SSME plume. Base heat shield tile chips fell in area of SSME #1 3 o'clock position. Another tile chip fell from upper left portion of view (frame 3202). LO2 T-0 umbilical retraction and TSM door closure nominal. A particle originating from top of TSM open door crossed FOV with no vehicle impact.

E-24
400 FPS
16mm

Camera is located on the MLP deck and views the LH OMS engine nozzle.

Focus : O.K.
F. O. V.: Too close, not centered.
Exposure: O.K.

Comments: Free burning hydrogen was visible at SSME ignition. OMS nozzle moved slightly at SSME ignition. Aft RCS paper covers were torn loose and pulled into SSME plume. Base heat shield tile chips were visible at 8 and 9 o'clock positions of SSME #2. At frame 2937 tile chip fell from base heat shield near OMS nozzle. Another tile chip from SSME #1, 9 o'clock position in frame 3664.

E-25
400 FPS
16mm

Camera is located on the east side of the MLP and views between Orbiter and ET/SRB during liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from LH2 umbilical at T-0 through early ascent. A RCS paper cover recirculated near SSME #3 before being drawn into plume. Numerous pieces of throat plug material were ejected out of SRB exhaust hole at T-0.

E-26
400 FPS
16mm

Camera is located on the west side of the MLP and views between Orbiter and ET/SRB during liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: Dark

Comments: Ice particles fell from ET/ORB umbilicals. Deluge water obscured FOV. Numerous particles moved across FOV after vehicle cleared frame.

E-27
400 FPS
16mm

Camera is located on the MLP deck and views RH SRB northwest holddown post (HDP #3) blast cover.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Numerous particles of throat plug material were ejected out of SRB exhaust hole at SRB ignition. Pieces of shim material were visible protruding upward from either side of holddown post #3. Holddown post blast covers closed nominally.

E-28
400 FPS
16mm

Camera is located on the MLP deck and views LH SRB northeast holddown post (HDP #7) blast cover.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Numerous particles of throat plug material were ejected out of SRB exhaust hole at T-0. One ordnance fragment fell from the HDP #8 stud hole/DCS. Holddown post blast covers closure was nominal.

E-30
400 FPS
16mm

Camera is located on the FSS 195 foot level and views LH SRB and sound suppression water troughs.

Comments: Camera malfunction - no data.

E-31 Camera is located on the FSS 95 foot level and views the LH Orbiter wing, body flap, and ET/Orbiter LH2 umbilical area.
100 FPS
16mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals during ascent. SRB thermal curtains appeared nominal. FSS deluge water obscured view.

E-33 Camera is located on the FSS 235 foot level and views the ET GH2 vent line and GUCP.
200 FPS
16mm

Focus : Soft.
F. O. V.: Slightly high.
Exposure: Underexposed.

Comments: SSME ignition and T-0 umbilical retraction caused ice particles to fall. Residual vapors emanated from flight QD. T-0 disconnect and separation appeared nominal.

E-34 Camera is located on FSS at 255 foot level and views upper Orbiter tile surfaces.
300 FPS
16mm

Focus : O.K.
F. O. V.: O.K.
Exposure: Underexposed at T-0, overexposed later.

Comments: Frost spots on -Y longeron were still present as vehicle passed FOV. No vehicle anomalies.

E-35 Camera is located on the FSS 255 foot level and views the mid-Orbiter/ET/SRB area.
300 FPS
16mm

Focus : Soft
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen was blown west. Ice particles fell from ET/ORB umbilicals. LH2 T-0 umbilical disconnect was nominal. Deluge water obscured FOV.

E-36 Camera is located on the FSS 255 foot level and views lower Orbiter, ET, SRB's, and water trough.
300 FPS
16mm

Comments: Camera did not run.

E-40 Camera is located on the FSS 275 foot level and views the ET ogive, SRB nosecone, and Orbiter tiled surfaces.
300 FPS
16mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Fwd RCS paper covers were intact through tower clear. Aft RCS paper covers had torn but portions still remained on the vehicle. Frost spot on -Y longeron still present as vehicle passed FOV. Ice particles fell from ET/ORB umbilicals during ascent. Foam outgassed on ET aft dome and SRB stiffener rings. No unusual ET/ORB umbilical vapors visible. Residual vapors still emanating from the Orbiter LH2 disconnect. Small particle appeared above leading RCC panel and drifted toward tank, but no contact with TPS occurred.

E-42 Camera is located on the FSS 185 foot level and views the GH2 vent line drop, deceleration, and latchback.
300 FPS
16mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Vent line retraction and latchback appeared nominal. No excess slack occurred in static lanyard cable due to recent facility modifications. Ice particles fell from GUCP and vent line at latchback. Facility debris was visible after vehicle had cleared pad.

E-43
200 FPS
16 mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: ROFI sparks fell into exhaust hole. No plume anomalies.

E-44
300 FPS
16mm

Camera is located on the FSS 155 foot level and views the LH OMS Pod leading edge tiles during ignition and liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Deluge water partially obscured view at T-0. Residual vapors emanated from Orbiter LH2 T-0 disconnect as vehicle ascended. T-0 umbilical separation and retraction appeared nominal. No visible anomalies on LH OMS pod leading edge.

E-48
300 FPS
16mm

Camera is located on the FSS 215 foot level (ET Intertank access arm structure) and views the GH2 vent line during GUCP disconnection, rotation, and latchback

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from GUCP at SSME ignition and T-0. GUCP separation and retraction appeared nominal. Residual vapors emanated from hydrogen vent line QD after separation.

E-50
60 FPS
16mm

Camera is located at camera site 1 at KNEE pad perimeter and views entire GH2 vent line and GUCP during rotation and latchback.

Comments: Camera malfunction - no data.

E-52
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: See film item E-54.

E-53
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of middle one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: See film item E-54.

E-54
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: ET/ORB umbilical ice fell at SSME ignition, T-0 and early ascent. Foam on SRB stiffener rings and ET aft dome outgassed. Aft RCS paper covers were torn loose and pulled into plume. GH2 vent arm retracted and latched nominally. Two frost spots were still present on +Y longeron during early ascent. ET aft dome charring occurred shortly after roll maneuver. Forward RCS paper covers were torn loose shortly after roll maneuver drawn into SSME plume, and burned creating orange streaks.

E-57
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: See film item E-59.

E-58
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of center one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: See film item E-59.

E-59 Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.
96 FPS
35mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Facility water operated nominally. GUCP ice fell away from vehicle at T-0. No additional TPS damage was visible from area of crack in intertank foam from T-0 through roll program. View near pad was obscured by plume. Tracking was lost early due to clouds.

E-60 Camera is located on north pad perimeter at camera site 1 and views the entire launch vehicle, FSS, and MLP zero level.
96 FPS
35mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB LH2 umbilical at SSME ignition and T-0. GH2 vent line retracted and latched nominally. Foam from ET aft dome and SRB stiffener rings outgassed. Aft RCS paper covers were torn loose and pulled into plume. Orange streaks from RCS paper covers occurred in the SSME plume.

E-61 Camera is located at camera site 2 on the east pad perimeter and views the launch vehicle, FSS, and MLP.
96 FPS
35mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen was blown under body flap. ET umbilical ice fell at SSME ignition, T-0 and early ascent. Aft RCS paper covers were torn loose and pulled into SSME plume. Vapors trailed from the base of the Orbiter speed brake. Frost spots were visible on the +Y longeron. Numerous particles were ejected out of SRB exhaust hole at T-0, none with smoking trails. Forward RCS paper covers were intact through tower clear. Several birds were visible north of the MLP flying away from pad.

E-62
96 FPS
35mm

Camera is located on the SE pad perimeter at camera site 3 and views entire vehicle, FSS, and MLP.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals. At SSME ignition ice fell from LO2 T-0 umbilical. Aft RCS paper covers were torn loose by engine acoustics and pulled into plume. At T-0 numerous particles are ejected out of SRB exhaust hole. Foam on ET aft dome and SRB stiffener rings outgassed after T-0. Forward RCS paper covers were intact as vehicle cleared the FSS. Three birds flying to the east and north of the pad were not near the vehicle.

E-63
96 FPS
35mm

Camera is located on SW pad perimeter at camera site 4 and views entire launch vehicle, FSS, and MLP.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen was blown west and up to LH OMS nozzle. Ice particles fell from LO2 T-0 umbilical at T-0. Aft RCS paper covers were torn loose and pulled into SSME plume. Ice from MLP transfer lines was shaken loose by engine acoustics. Debris under RSS was blown west by plume as vehicle ascended. View was quickly obscured by plume. Two birds visible NW of pad flying away.

E-64
96 FPS
35mm

Camera is located on NW pad perimeter at camera site 6 and views entire launch vehicle, FSS, and MLP.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Aft RCS paper covers were torn loose and pulled into plume by aspiration. Foam on ET aft dome and SRB stiffener rings outgassed after T-0.

E-76 | 96 FPS | 35mm

Camera is located on SE pad perimeter at camera site 3 and views SSME engines #1 and #3 and the RH OMS engine nozzle.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen was blown west and up to the LH OMS nozzle. Ice particles fell from the ET/ORB umbilicals at SSME ignition and T-0. Aft RCS paper covers were torn loose and pulled into SSME plume. No tile damage visible on the trailing edge of the Orbiter rudder/speed brake. LO2 T-0 umbilical disconnect appeared nominal. Tile surface coating material fell from elevon upper surfaces during SSME ignition. Residual vapors were visible from both Orbiter T-0 disconnects.

E-77 | 96 FPS | 35mm

Camera is located on SW pad perimeter at camera site 4 and views SSME engines #1 and #2 and the LH OMS engine nozzle.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen was blown west and up to LH OMS nozzle. Ice particles fell from LO2 T-0 umbilical. No trailing edge tile damage was visible on the rudder/speed brake.

E-79A | 6 FPS | 16 MM

Camera is located on east pad perimeter at camera site 2 and views ET nosecone, louver, and ogive.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: ET twang appeared nominal.

E-201 | 30 FPS | 70mm

UCS-9 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

Comments: Little data, view obscured by clouds.

E-202 U247L116 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Comments: Little data, view obscured by clouds.

E-203 UCS-16 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Comments: Little data, view obscured by clouds.

E-204 PAFB IGOR tracking of launch vehicle from
48 FPS acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Lack of condensate on ET aft dome caused foam to outgas shortly after liftoff. Forward RCS paper covers were torn loose and cause orange streaks when pulled into the SSME plume. View lost early due to clouds.

E-205 Shiloh IFLOT tracking of launch vehicle from
48 FPS acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SRB separation appeared nominal. Majority of view obscured by clouds. No vehicle anomalies.

E-206 Melbourne Beach ROTI tracking of launch vehicle
48 FPS from acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Very little data due to cloud cover.

E-207
96 FPS
35mm

UCS-10 MIGOR tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : O.K.
F. O. V.: O.K., FOCAL LENGTH INCREASED FROM 180 TO 360 INCHES
Exposure: O.K.

Comments: Foam on ET aft dome and SRB stiffener rings outgassed. Charring was visible on ET aft dome after roll maneuver. Pieces of LH2 purge barrier baggie material were torn loose during roll program at frames 36-03, 45-08, and 55-11. A large portion of LO2 purge barrier baggie material flapped in the air flow during roll program and was torn loose shortly afterwards in frame 69-06. Forward RCS paper covers fell aft after roll. An orange flash, caused by a piece of RCS paper cover, occurred in the SSME plume at frame 89-02. A piece of SRB thermal curtain tape came loose near the nozzle extension, separated completely in the vicinity of HDP #7 (frame 227-09), and was lost from view against the SRB plume. This occurred at approximately 41 seconds MET.

E-208
48 FPS
35mm

Cocoa Beach DOAMS tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Very little data due to cloud cover.

E-209
30 FPS
70mm

SHILOH IFLOT intermediate tracking of launch vehicle from acquisition to LOV.

Comments: Very little data due to cloud cover.

E-211
96 FPS
35mm

UCS-13 IFLOT intermediate tracking of forward portion of ORB and ET from acquisition to LOV.

Focus : Soft.
F. O. V.: O.K.
Exposure: O.K.

Comments: Poor resolution early in flight due to atmospheric conditions. Clouds and plume obscure vehicle later in flight.

E-212 | UCS-23 MIGOR tracking of launch vehicle from acquisition to LOV.
64 FPS
35mm

Focus : O.K.
F. O. V.: O.K., FOCAL LENGTH INCREASED FROM 180 TO 360 INCHES
Exposure: O.K.

Comments: Foam on ET aft dome and SRB stiffener rings outgassed. A large portion of LO2 purge barrier baggie material was torn loose at frame 46-04 shortly after roll. Fwd RCS paper covers fell aft and caused orange streaks when drawn into plume at frame 50-10. Bright spots near SSME #1 at frame 310-00 are the SSME closeout blankets and a reflection off the flat surface of the OMS pod. SRB plume recirculation was typical. SRB propellant slag/clinkers fell out of the SRB plume at tailoff. SRB separation was nominal. SRB slag was visible after separation.

E-213 | UCS-12 MOTS tracking of forward portion of ORB and ET from acquisition to LOV.
96 FPS
35mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Foam on ET aft dome and SRB stiffener rings outgassed. Ice particles fell from ET/ORB umbilicals during ascent. Charring occurred on ET aft dome. LH2 purge barrier baggie material was torn loose during and after roll maneuver. A large portion of LO2 purge barrier baggie material was torn loose shortly after roll maneuver (frame 101-03). Forward RCS paper covers fell aft and were pulled into plume. An orange flash, caused by a piece of RCS paper, occurred in SSME plume (frame 78-11). Two bright objects, possibly pieces of aft skirt instafoam, fell from RH aft skirt near HDP #1/aft ring at frame 103-02 and near HDP #3/aft ring at frame 113-13 at 22 and 24 seconds MET, respectively. Shortly after the roll maneuver, clouds obscured view.

E-217 | Beach Road IFLOT close-in tracking of launch vehicle during ignition, liftoff, and early portion of flight through LOV.
30 FPS
70mm

Comments: Little data, view obscured by clouds.

E-220
96 FPS
35mm

U247L116 IFLOT close-in tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Lack of condensate on the ET aft dome caused early outgassing of the foam. Forward RCS paper covers were torn loose and pulled into SSME plume. SRB separation nominal.

E-221
96 FPS
35mm

UCS-3 IFLOT close-in tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.

Comments: No data - camera malfunction.

E-222
96 FPS
35mm

Beach Road IFLOT close-in tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: Underexposed.

Comments: SRB stiffener ring foam outgassed during flight. LO2 purge barrier baggie material was torn loose shortly after roll program. Forward RCS paper covers fell aft. A bright object fell from the RH SRB aft skirt/aft ring area at 22 seconds MET. Cloud cover obscured view shortly after roll.

E-223
96 FPS
35mm

UCS-9 IFLOT intermediate tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Foam on ET aft dome and SRB stiffener rings outgassed. ET aft dome charring occured shortly after roll maneuver. Ice particles fell from ET/ORB umbilical during ascent. Forward RCS paper covers fell aft shortly after roll maneuver. A portion of LO2 purge barrier baggie material was torn loose shortly after roll (frame 97-12).

E-224 UCS-16 IFLOT close-in tracking of entire launch
100 FPS vehicle during ignition, liftoff, and early flight
35mm through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals. Foam on ET aft dome and SRB stiffener rings outgassed. Aft/Fwd RCS paper covers were torn loose and pulled into SSME plume. ET aft dome charring began prior to roll maneuver. At 06:49:20.697 and 06:49:23.448 GMT, white particles fell from SRB aft skirt area. These particles were most likely pieces of Instafoam.

VIDEO ITEMS

OTV 101 Views aft end of Orbiter from the FSS 255 foot
B/W M-II level.

Comments: Overexposed.

OTV 103 Views GUCP and GH2 vent line.
B/W M-II

Comments: Vehicle twang normal. Small pieces of ice fell from GUCP. GH2 vent line disconnect and retract nominal.

OTV-109 Views ET/Orbiter LH2 umbilical area from the 95
B/W M-II foot level of the FSS.

Comments: SSME ignition caused ice/frost to shake loose and fall from umbilical. Some ice impacted cable tray but no TPS damage visible.

OTV 141 Views and tracks vehicle from camera site 2.
B/W

Comments: Facility water activated properly. SSME ignition appeared normal. No vehicle or plume anomalies. Foam outgassed on ET aft dome and SRB stiffener rings.

OTV 143 Views east side of launch vehicle and pad from
B/W camera site 2.

Comments: Facility water activated properly. SSME ignition nominal. Ice fell from ET/ORB umbilical. GH2 vent line latched and did not rebound.

OTV 148 Launch and tracking view from camera site 6.
B/W

Comments: No anomalies during facility water activation. No vehicle or plume anomalies.

OTV 149 Views Orbiter LO2 T-0 umbilical from MLP deck.
B/W M-II

Comments: Ice particles fell from T-0 at SSME ignition. LO2 T-0 disconnect and retract normal. RCS paper covers and ice fell during ascent.

OTV 150 Views Orbiter LH2 T-0 umbilical from SW MLP deck.
B/W M-II

Comments: Small parts tag reflected light. Vehicle twang normal. LH2 T-0 disconnect and retraction normal. Residual vapors from Orbiter T-0 trailed aft.

OTV 151 Views main engine cluster.
B/W M-II

Comments: SSME ignition appeared normal. LH2 TSM door closed properly. No vehicle anomalies.

OTV 154 Views ET/Orbiter LO2 umbilical and Orbiter RH wing
B/W M-II

Comments: Overexposed and synchronization problem. SSME ignition caused ice to fall from both umbilicals.

OTV 155 Views RH SRB and underside of Orbiter RH wing.
B/W M-II

Comments: SSME ignition and gimbal normal. Free burning hydrogen blown under body flap. Ice fell from both ET/ORB umbilicals.

OTV 156 Views LH SRB and underside of Orbiter LH wing.
B/W M-II

Comments: Overexposed.

OTV 160 Views ET nosecone and NE louver from water tower.
Color M-II

Comments: Light coating of frost in NE louvers. Facility water activated properly. Vehicle twang normal. GH2 vent line retract and latchback appeared nominal.

OTV 161 Views ET nosecone and SW louver from the FSS.
Color M-II

Comments: Light coating of frost on SW louver. No TPS anomalies on nosecone, fairing, or footprint area. Vehicle twang normal. Tumble valve cover was configured properly.

OTV 163 Views ET/Orbiter umbilical and Orbiter T-0
Color M-II umbilical from the FSS.

Comments: Normal venting of LH2 umbilical helium purge gas. SSME ignition caused large quantity of ice/frost to fall from umbilical, no TPS damage visible. Free burning hydrogen blown under body flap. T-0 disconnect and retraction nominal. Residual vapors trailed vehicle from LH2 T-0 area. Flash above crossbeam as vehicle rises was caused by eastern bank of Xenon lights. Vapors from LH2 feedline and recirculation line bellows were probably backlit frost particles.

OTV 170 Views overall vehicle from SE direction.
Color M-II

Comments: Facility and MLP LH2 skid fire suppression water activated properly. SSME ignition appeared normal. Facility debris object, probably a cable tray cover, was visible above OAA white room as vehicle cleared frame.

OTV 171 Views overall vehicle from SW direction.
Color M-II

Comments: SSME ignition appeared normal. Free burning hydrogen rose as high as LH OMS pod. Vertical stabilizer shook slightly from side to side. RCS paper cover pieces and ice particles fell, an expected occurrence.

STI (C/S 2) Infrared view from camera site 2.
B/W VHS

Comments: APU start and run appeared normal. No unusually cold or hot areas were apparent in the nosecone area after GOX hood retraction. At SSME start, free burning hydrogen was momentarily blown underneath the body flap where it rose to the hingeline. SSME start and run were nominal. Radiative heating effects from the exhaust plumes were visible on the ET aft dome and the orbiter body flap lower surface as the vehicle ascended. No facility fires were detected after launch.

STI (RSS) Infrared view from RSS roof.
B/W VHS

Comments: APU start and run appeared normal. No unusually cold or hot areas were apparent in the nosecone area upon GOX hood retraction. AT SSME start, free burning hydrogen was momentarily blown upward along the LH OMS pod, rising approximately half the pod length. SSME start and run were nominal. No facility fires were detected after launch.

TV-2 Views launch from convoy position at SLF.
Color M-II

Comments: View too distant for detail. Vehicle soon obscured by clouds.

TV-4B Views entire vehicle from Beach Road IFLOT Site.
Color M-II

Comments: SSME ignition and T-0 appeared nominal. Foam on ET aft dome and SRB stiffener rings outgassed. No plume anomalies during ascent. SRB separation nominal.

TV-5 Views launch from VAB roof.
Color M-II

Comments: View too distant for detail. No vehicle anomalies.

TV-7 Views entire launch vehicle from camera site 2
Color M-II on east side of pad.

Comments: Facility water activated properly. SSME ignition was normal. Vehicle twang normal. No anomalies visible at T-0.

TV-13 Cocoa Beach DOAMS long range tracker.
Color M-II

Comments: Little data, vehicle mostly obscured by clouds.

TV-16 View from helicopter orbiting west of VAB.
Color M-II

Comments: Not available for this launch.

TV-18 Malabar ITEK long range tracker.
Color M-II

Comments: No data. Acquisition occurred after SRB separation.

ET-204 Patrick IGOR long range tracker.
Color M-II

Comments: Foam outgassed on ET aft dome. Vehicle obscured by clouds.

ET-206 Melbourne Beach ROTI long range tracker.
Color M-II

Comments: Vehicle obscured by clouds.

ET-207 UCS-10 MIGOR long range tracker.
Color M-II

Comments: SRB stiffener ring foam outgassed shortly after lift-off. Aft dome was outgassing prior to tower clear. Roll maneuver was normal. No vehicle anomalies.

ET-208 Cocoa Beach DOAMS long range tracker.
Color M-II

Comments: Little data, vehicle mostly obscurred by clouds.

ET-212 UCS-23 MIGOR long range tracker.
Color M-II

Comments: Underexposed. No plume anomalies. SRB separation appeared normal. Numerous pieces of SRB propellant slag fell from plumes after separation.

ET-213 UCS-12 MOTS long range tracker.
Color M-II

Comments: No vehicle anomalies at T-0. ET aft dome foam began to outgas after T-0 and char after the roll maneuver.

7.2 ON-ORBIT FILM DATA REVIEW

F-022 16mm	Views LH SRB separation from Orbiter ET/ORB LH2 umbilical. Lower region of ET is also in FOV.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: CAMERA DID NOT OPERATE PROPERLY - ET SEPARATION WAS NOT RECORDED. NORMAL TPS EROSION OCCURRED ON ALL TRAILING EDGE SURFACES. INSIGNIFICANT LOSS OF TPS AND CHARRING WAS VISIBLE ON ET AFT DOME. SRB SEPARATION WAS NORMAL. NO SRB CASE OR JOINT ANOMALIES WERE VISIBLE.

STILL 70mm	Views taken by flight crew of External Tank after separation from the Orbiter

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: EXAMINATION OF THE EXTERNAL TANK POST-SEPARATION PHOTOGRAPHY REVEALED THE PRESENCE OF AT LEAST TWELVE TPS DIVOTS ON THE INTERTANK-TO-LH2 TANK FLANGE. OF THE TWELVE DIVOTS, SEVEN WERE LOCATED ON THE +Y SIDE OF THE TANK AND FIVE WERE LOCATED ON THE -Y SIDE. THE LARGEST SIX DIVOTS HAD A MAJOR DIMENSION OF APPROXIMATELY EIGHT TO TEN INCHES. A THIRTEENTH DIVOT WAS VISIBLE IN THE UPPER LH2 TANK ACREAGE AREA NEAR THE LH BIPOD CLOSEOUT. THESE DIVOTS MAY HAVE CONTRIBUTED TO THE HIGHER THAN AVERAGE NUMBER OF ORBITER LOWER SURFACE TPS DEBRIS HITS (132) ON THIS MISSION. NO TPS DIVOTS WERE VISIBLE ON THE LO2 TANK-TO-INTERTANK FLANGE.

NO TPS DIVOTS WERE VISIBLE IN THE ACREAGE AREAS OF THE LO2 TANK OR INTERTANK. ASCENT AEROHEATING/CHARRING ON THE LO2 TANK OGIVE, AROUND THE FORWARD ET/SRB ATTACH POINTS, AND ON THE LH2 TANK AFT DOME AND AFT HARDPOINT APPEARED NORMAL. NO ANOMALIES WERE VISIBLE ON THE ET FLIGHT DOOR, GUCP, ET/SRB ATTACH POINTS, AND ET/ORBITER ATTACH POINTS.

7.3 LANDING FILM DATA REVIEW

E-1006 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ORBITER WAS ONLY VISIBLE AT TOUCHDOWN PASSING THROUGH THE XENON LIGHTS. NO VEHICLE ANOMALIES. ORBITER WAS NOT VISIBLE DURING ROLLOUT AND WHEEL STOP DUE TO DARK CONDITIONS.

E-1007 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ORBITER WAS ONLY VISIBLE AT TOUCHDOWN PASSING THROUGH THE XENON LIGHTS. NO VEHICLE ANOMALIES. ORBITER WAS NOT VISIBLE DURING ROLLOUT AND WHEEL STOP DUE TO DARK CONDITIONS.

E-1009 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ORBITER WAS ONLY VISIBLE AT TOUCHDOWN PASSING THROUGH THE XENON LIGHTS. NO VEHICLE ANOMALIES. ORBITER WAS NOT VISIBLE DURING ROLLOUT AND WHEEL STOP DUE TO DARK CONDITIONS.

E-1017 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NO VEHICLE ANOMALIES AT TOUCHDOWN AND ROLLOUT. NO TPS DETAILS DUE TO DARK CONDITIONS.

TV-1 Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: NORMAL NOSE-UP ATTITUDE DURING FLARE. RH MLG TOUCHED DOWN FIRST FOLLOWED ALMOST IMMEDIATELY BY LH MLG. NOSE LANDING GEAR TOUCHDOWN WAS SMOOTH. NO VEHICLE ANOMALIES DURING ROLLOUT.

TV-2 Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: ORBITER ALREADY ROLLING OUT WHEN ACQUIRED. NO VEHICLE ANOMALIES.

TV-3 Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: TOO DISTANT FOR DETAIL. NO VEHICLE ANOMALIES.

TV-4 Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: ORBITER ALREADY ROLLING OUT WHEN ACQUIRED. NO VEHICLE ANOMALIES.

LRO Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: TOO DISTANT FOR DETAIL. NO VEHICLE ANOMALIES.

INFRARED Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: EXCELLENT VEHICLE CONTRAST AGAINST THE NIGHT SKY. NO VEHICLE ANOMALIES DURING FINAL APPROACH AND FLARE. LANDING GEAR DEPLOYMENT WAS NORMAL. NOSECAP AND WING LEADING EDGE RCC PANELS WERE WARMEST AREAS ON ORBITER. RH MAIN LANDING GEAR TOUCHED DOWN FIRST. TIRES GOT HOT AT TOUCHDOWN AND SPIN-UP, THEN COOLED SOME-WHAT DURING ROLLOUT. SAME WITH NOSE LANDING GEAR. APU EXHAUST NEAR VERTICAL STABILIZER WAS NORMAL. RCS THRUSTER NOZZLES WERE STILL WARM.

8.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 4 December 1990 from 0800 to 1130 hours. In general, the SRB's appeared to be in good condition.

8.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nosecap was not recovered. The RH frustum had no areas of missing TPS but had 30 MSA-2 debonds over fasteners (Figure 5). Two BSM covers were fully opened but the other two had been bent by parachute riser entanglement after water impact.

The RH forward skirt exhibited no debonds or missing TPS (Figure 6). The phenolic plates on both RSS antennae were not delaminated. The forward separation bolt and electrical cables appeared to have separated cleanly. K5NA closeouts on the inboard corners of the RSS interface cable tray were intact. The frustum severance ring, utilizing new pin retainer clips and lockwire, was missing no pins.

The Field Joint Protection System (FJPS) closeouts were generally in good condition with the exception of a crack (2"x0.1"x0.20" deep) in the center field joint K5NA closeout at the 270 degree trunnion location. Minor trailing edge damage to the FJPS and GEI cork runs were attributed to debris hits from nozzle extension severance.

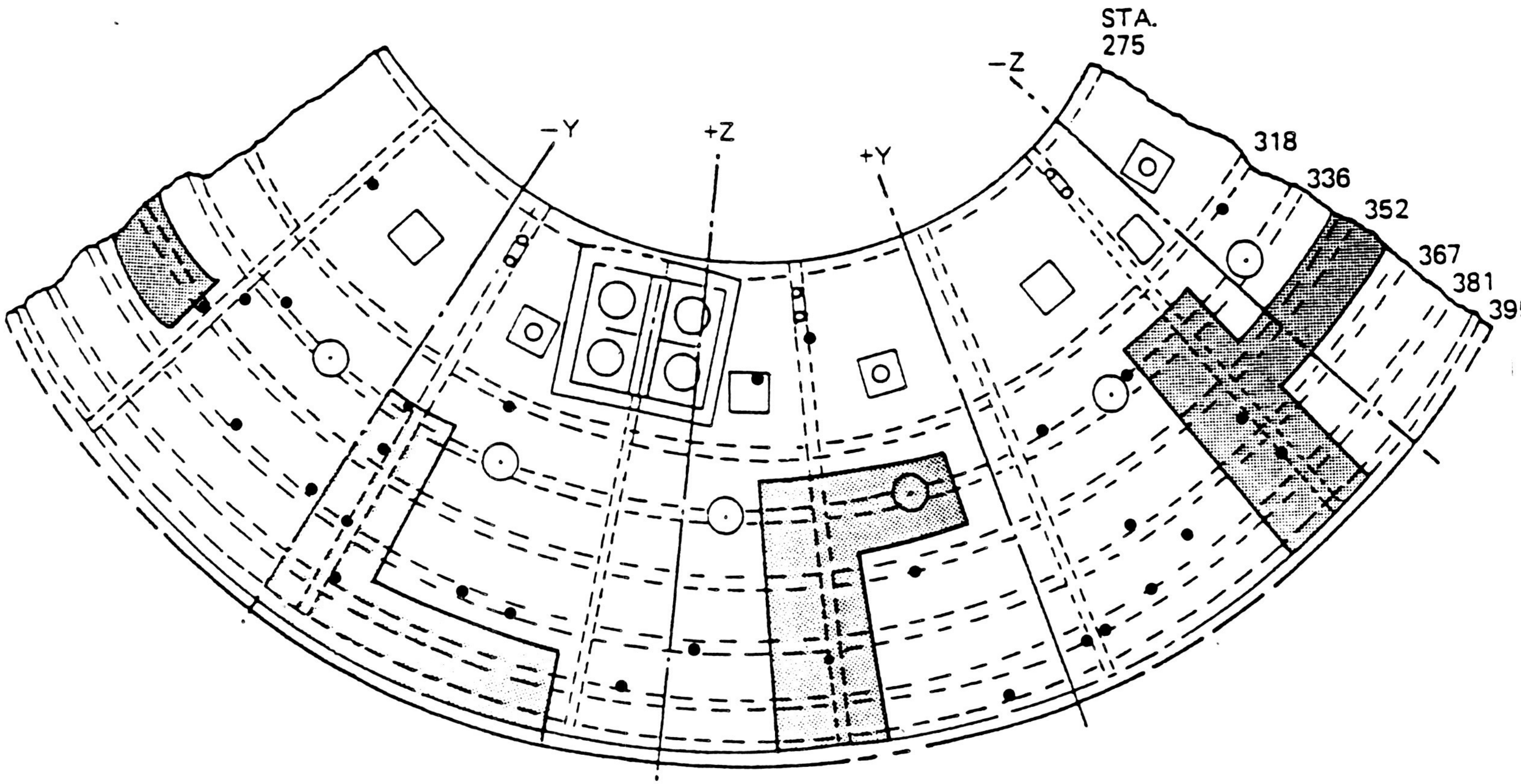
The ET/SRB aft struts, ETA ring, IEA, and aft booster stiffener rings appeared undamaged. K5NA closeouts on the IEA covers were intact, though Hypalon paint had blistered in localized areas.

The phenolic material on the kick ring delaminated in only a few locations. None of the K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring during ascent. The aft skirt acreage TPS was in good condition. K5NA was missing from all aft BSM nozzles (Figure 7).

The TVC system appeared to be undamaged. Instafoam was missing from the aft ring around the aft skirt feet, HPU exhaust horns, and the SRB T-0 umbilical.

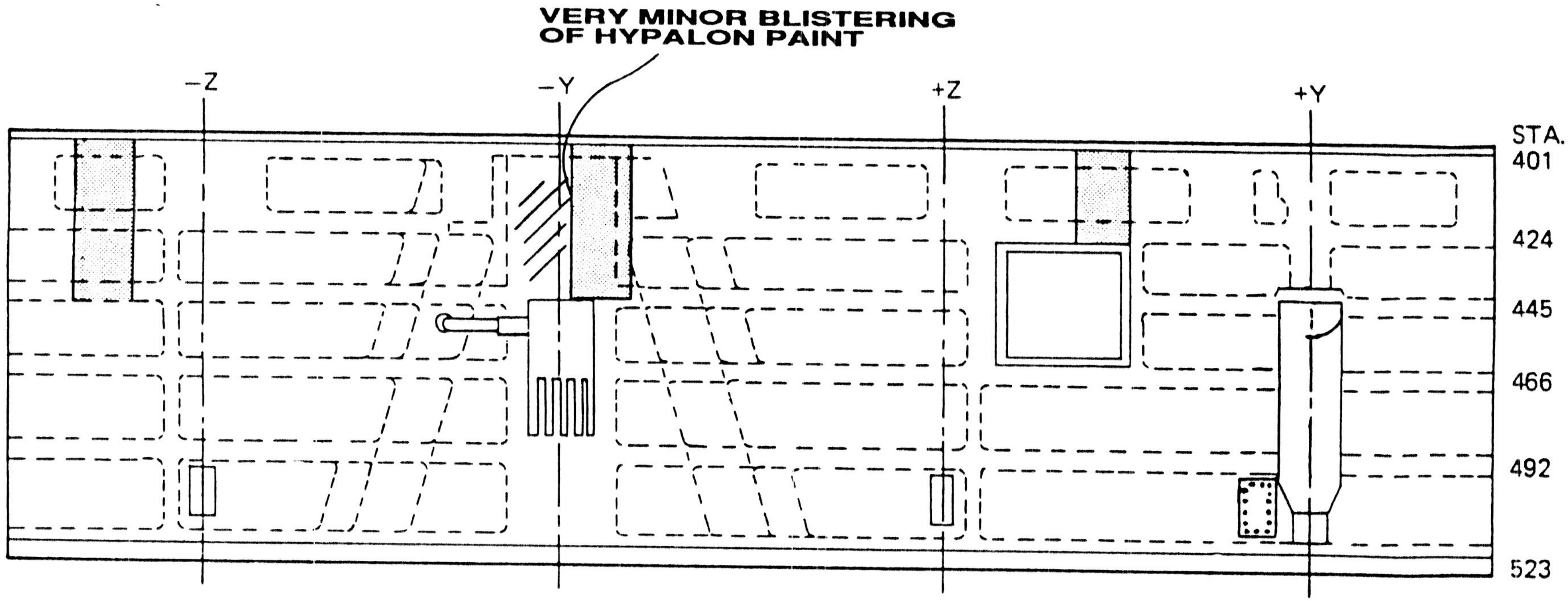
Debris Containment System (DCS) plungers for HDP #2 and #4 were properly seated, but frangible nut halves prevented the HDP #1 and #3 plungers from seating. A 10"x2" portion of EPON shim material was missing from the HDP #4 foot prior to water impact.

FIGURE 5. RIGHT SRB FRUSTUM



MISSING TPS	DEBONDS
NONE	30 DEBONDS OVER FASTENERS

FIGURE 6. RIGHT SRB FWD SKIRT

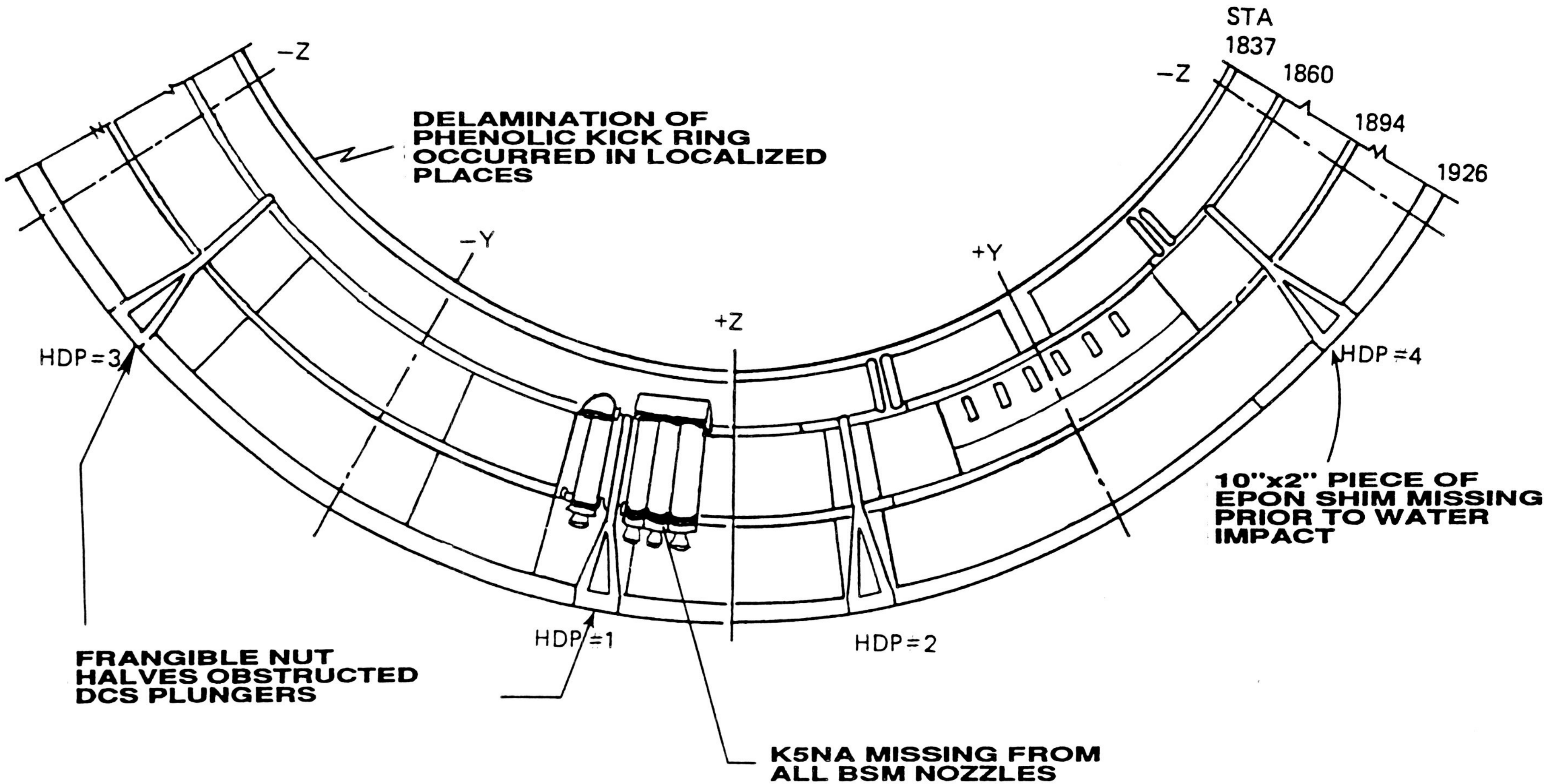


TPS MISSING
NONE

DEBONDS
NONE

NOTES
PHENOLIC PLATES ON BOTH RSS ANTENNAE WERE NOT DELAMINATED.

FIGURE 7. RIGHT SRB AFT SKIRT EXTERIOR TPS



8.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nosecap was not recovered. The LH frustum exhibited no missing TPS but had 21 MSA-2 debonds over fasteners (Figure 8). Two BSM covers were fully opened but the lower left and lower right covers had been bent by parachute riser entanglement after water impact. Hypalon paint had blistered along the 395 ring.

The LH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were not delaminated (Figure 9). The forward separation bolt and electrical cables appeared to have separated cleanly. The K5NA closeouts on the inboard corners of the RSS interface cable tray were intact. Hypalon paint had blistered on the systems tunnel cover fairing. The frustum severance ring, utilizing new pin retainer clips and lockwire, was missing no pins.

The Field Joint Protection System (FJPS) closeouts were in good condition. Minor trailing edge damage to the FJPS and GEI cork runs were attributed to debris hits from nozzle extension severance.

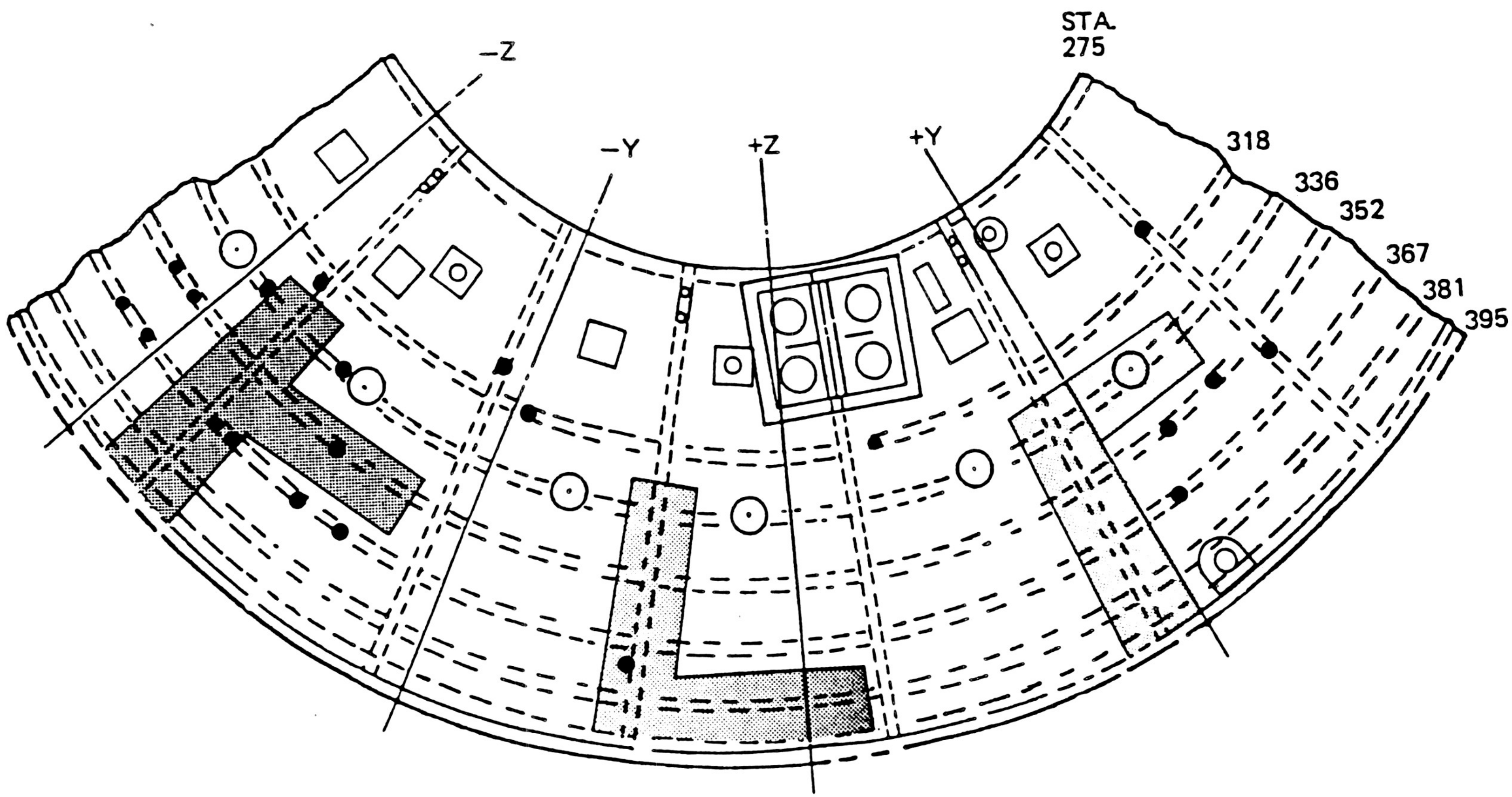
The ET/SRB aft struts, ETA ring, IEA, and aft booster stiffener rings appeared undamaged. K5NA closeouts on the IEA covers were intact, though Hypalon paint had blistered in localized areas.

The phenolic material on the kick ring delaminated in several locations. None of the K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring during ascent. The aft skirt acreage TPS was in good condition (Figure 10). K5NA was missing from all aft BSM nozzles.

The TVC system appeared to be undamaged. Instafoam was missing from the aft ring around the aft skirt feet, HPU exhaust horns, and the SRB T-0 umbilical.

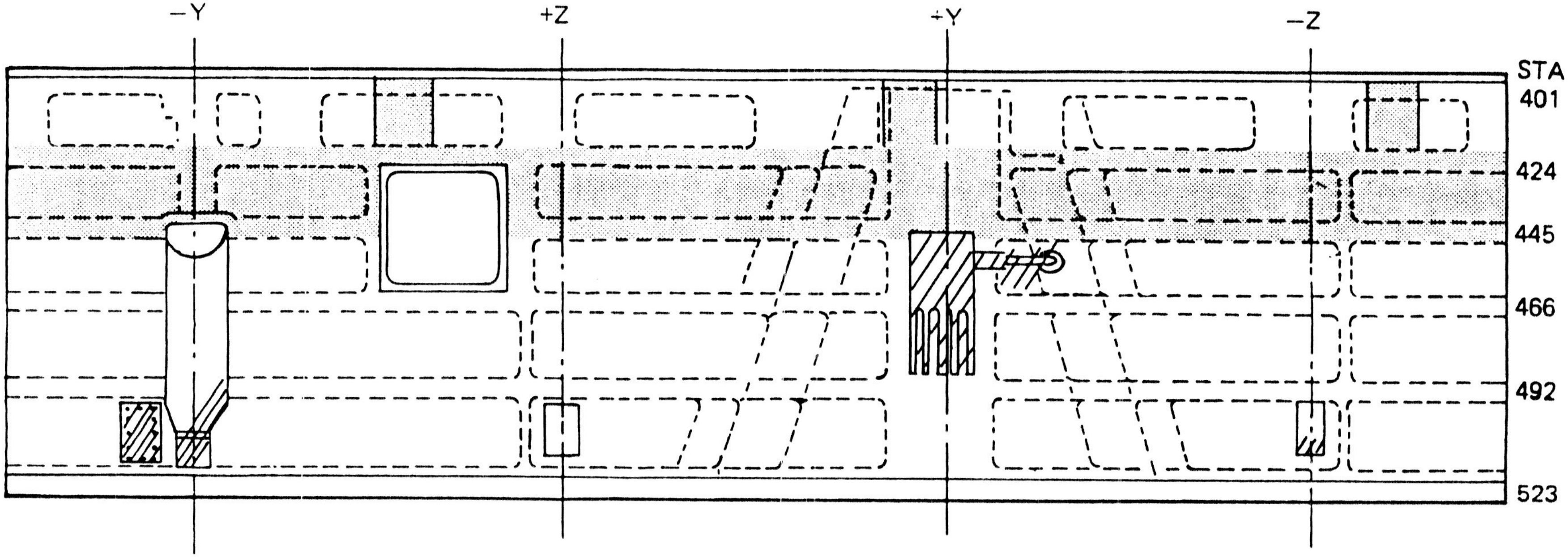
Debris Containment System (DCS) plungers for HDP #7 and #8 were properly seated, but a frangible nut half prevented the HDP #5 from seating properly. In addition, ordnance fragments prevented the HDP #6 plunger from seating. Two pieces of EPON shim sidewall material (10"x1" and 6"x1/2"), which should have remained bonded to the HDP #5 shoe, were found attached to the sides of the aft skirt foot after retrieval.

FIGURE 8. LEFT SRB FRUSTUM



TPS MISSING	DEBONDS	NOTES
NONE	21 DEBONDS OVER FASTENERS	HYPALON PAINT BLISTERED ALONG 395 RING

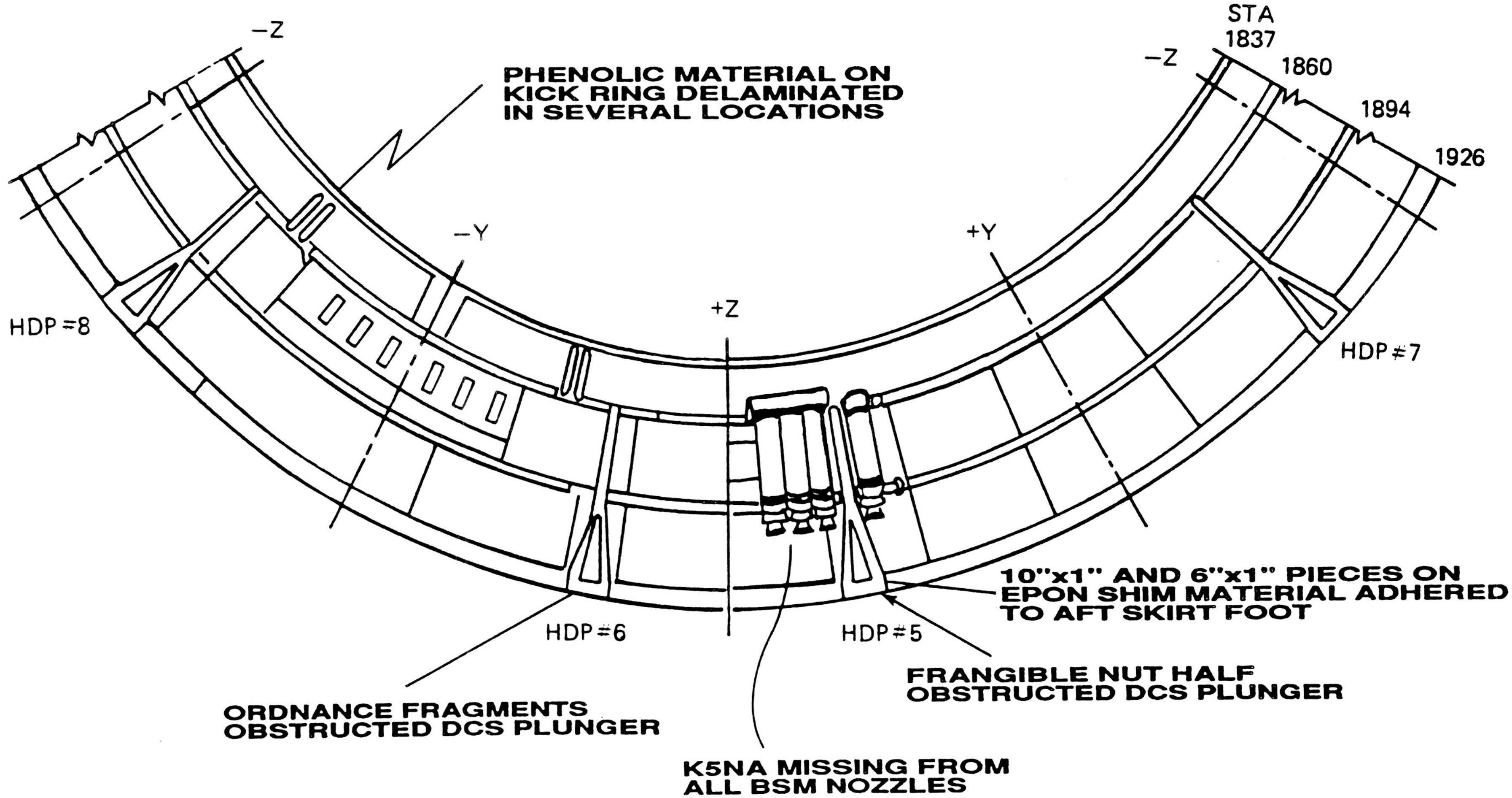
FIGURE 9. LEFT SRB FWD SKIRT



TPS MISSING	DEBONDS	NOTES
NONE	NONE	THE PHENOLIC PLATES ON BOTH RSS ANTENNAE WERE NOT DELAMINATED.

//// BLISTERED HYPALON PAINT

FIGURE 10. LEFT SRB AFT SKIRT EXTERIOR TPS



8.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 58% and individual holddown post retention percentages as listed:

HDP #	Overall %	% of Nut without 2 large halves	% of Ordnance
1	36	47	9
2	28	34	12
3	13	5	37
4	99	99	96
5	52	46	65
6	96	99	87
7	97	99	93
8	42	34	61

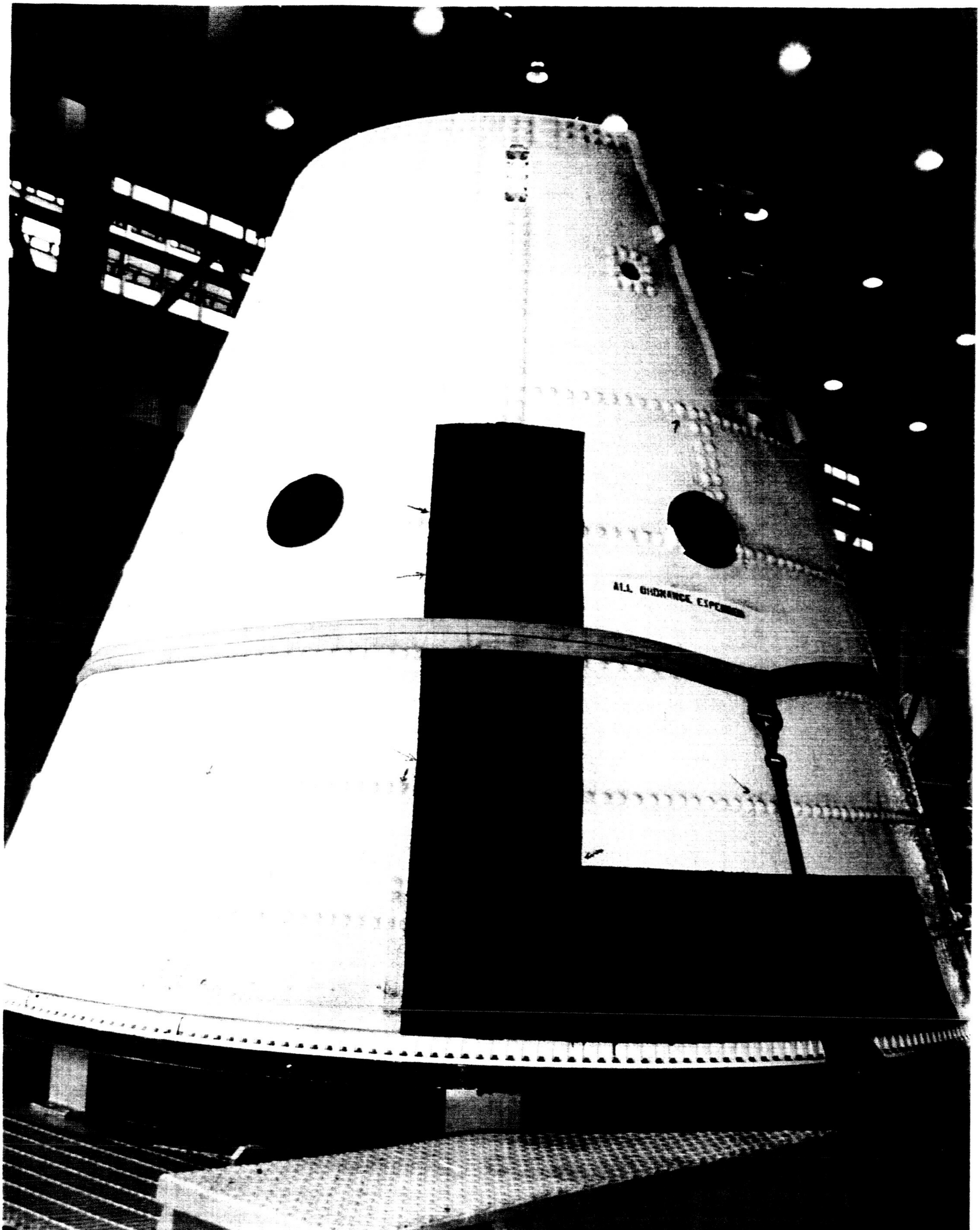
The minimum allowable retention per NSTS-07700 is 90 percent. A PR was taken against the retention performance of the Debris Containment System on STS-35. The DCS performance has been the subject of a previous IFA.

The RH parachute release ordnance did not fire and the failure was taken as an IFA. The cause had been narrowed down to a signal conditioner/impact switch malfunction.

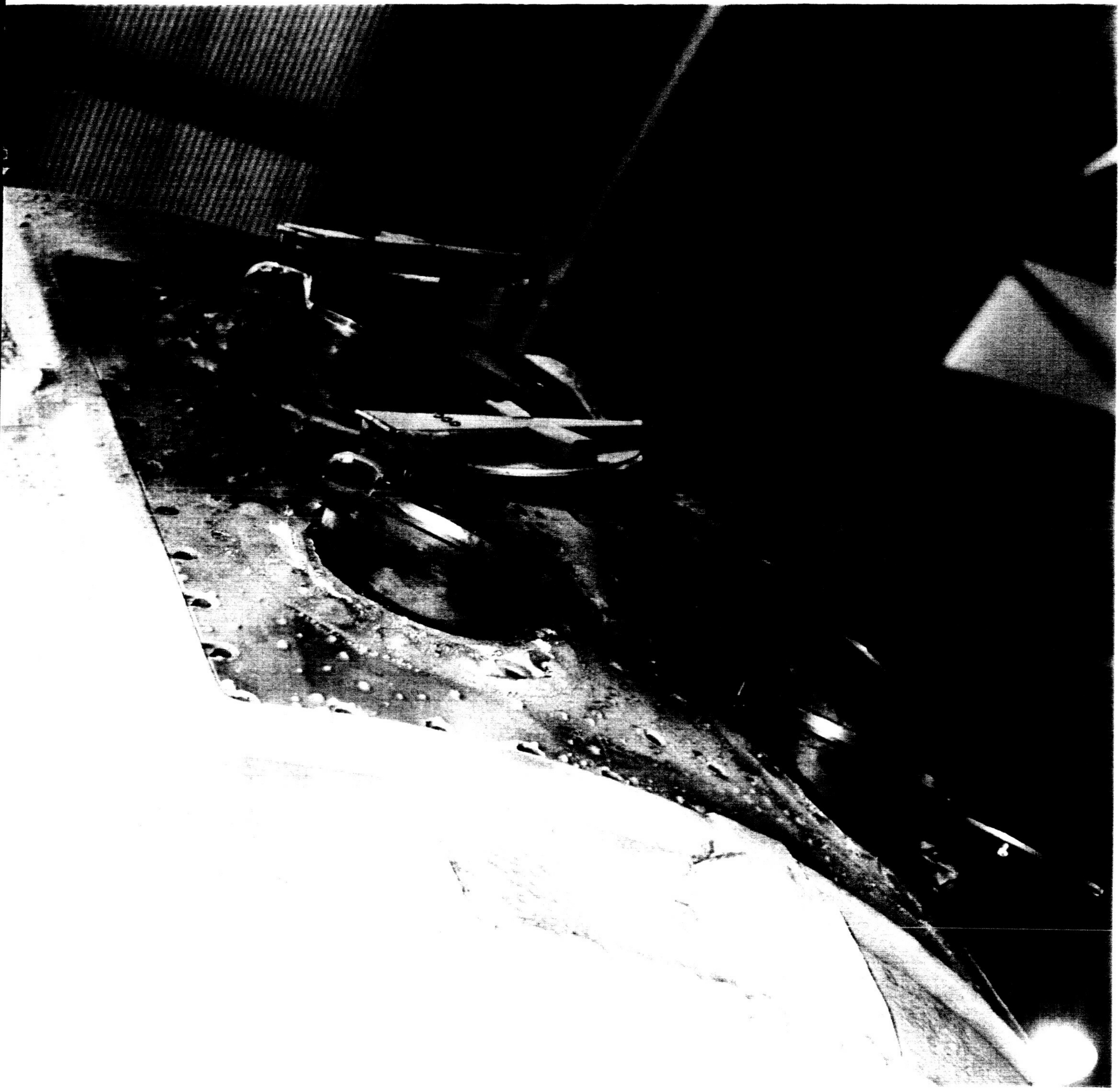
Both RH and LH ignitors experienced through-putty blowholes allowing combustion gases to impinge on the Gask-o-seal retainers. cadmium plating had corroded away to within 0.010 inches of the primary seal. This condition was not documented on a Problem Report based on previous IFA rationale.

The RH nozzle-to-aft dome factory joint experienced a terminated blowhole at 130 degrees and light sooting within 0.050 inches of the wiper O-ring, a first time occurrence since return to flight. A second blowhole occurred at 317 degrees. Both blowholes were assembly induced and resulted in an IFA.

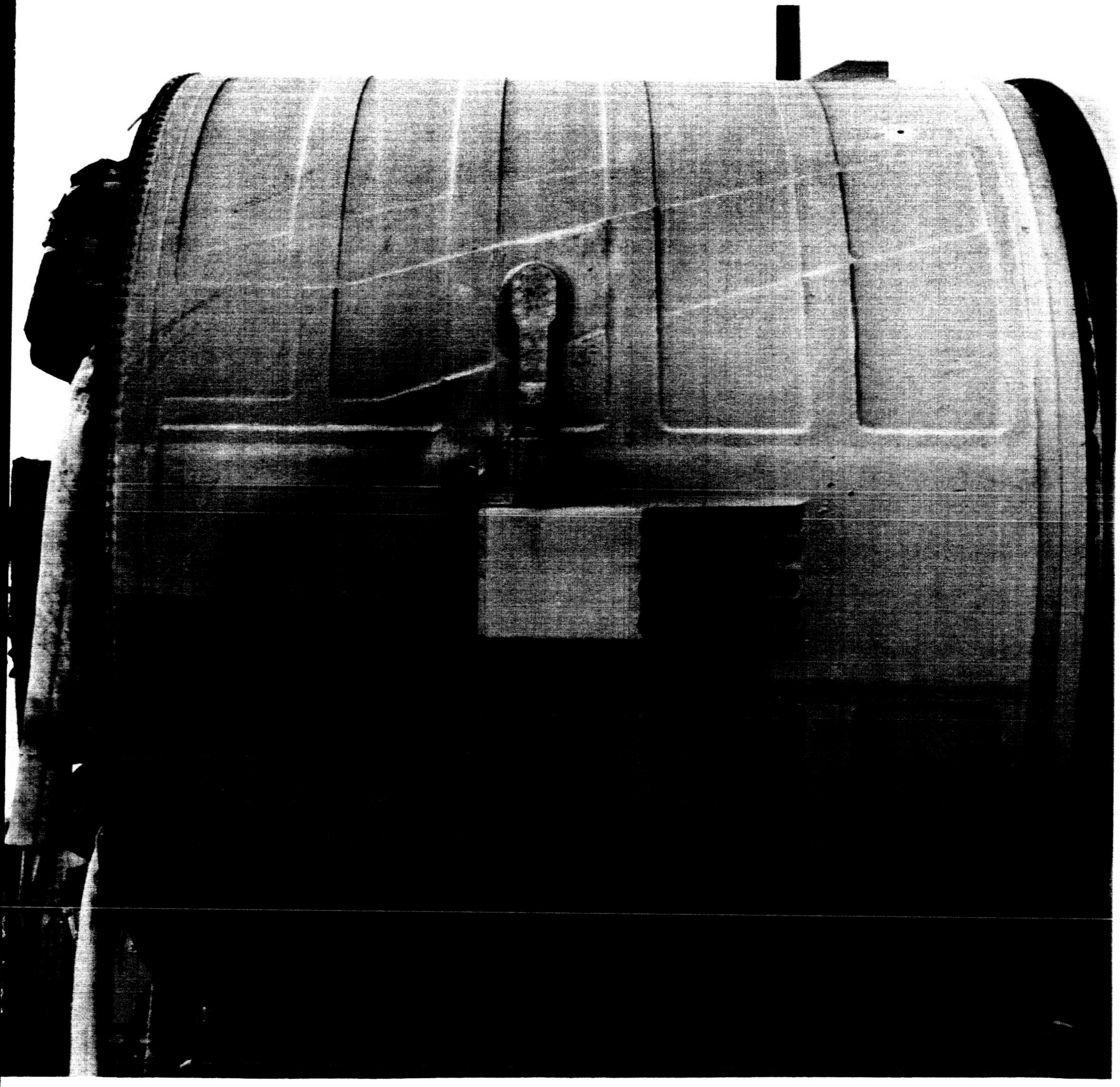
SRB Post Launch Anomalies are listed in Section 11.3.



Post flight condition of the RH frustum. There were 30 MSA-2 debonds over fasteners, but no areas of missing TPS.

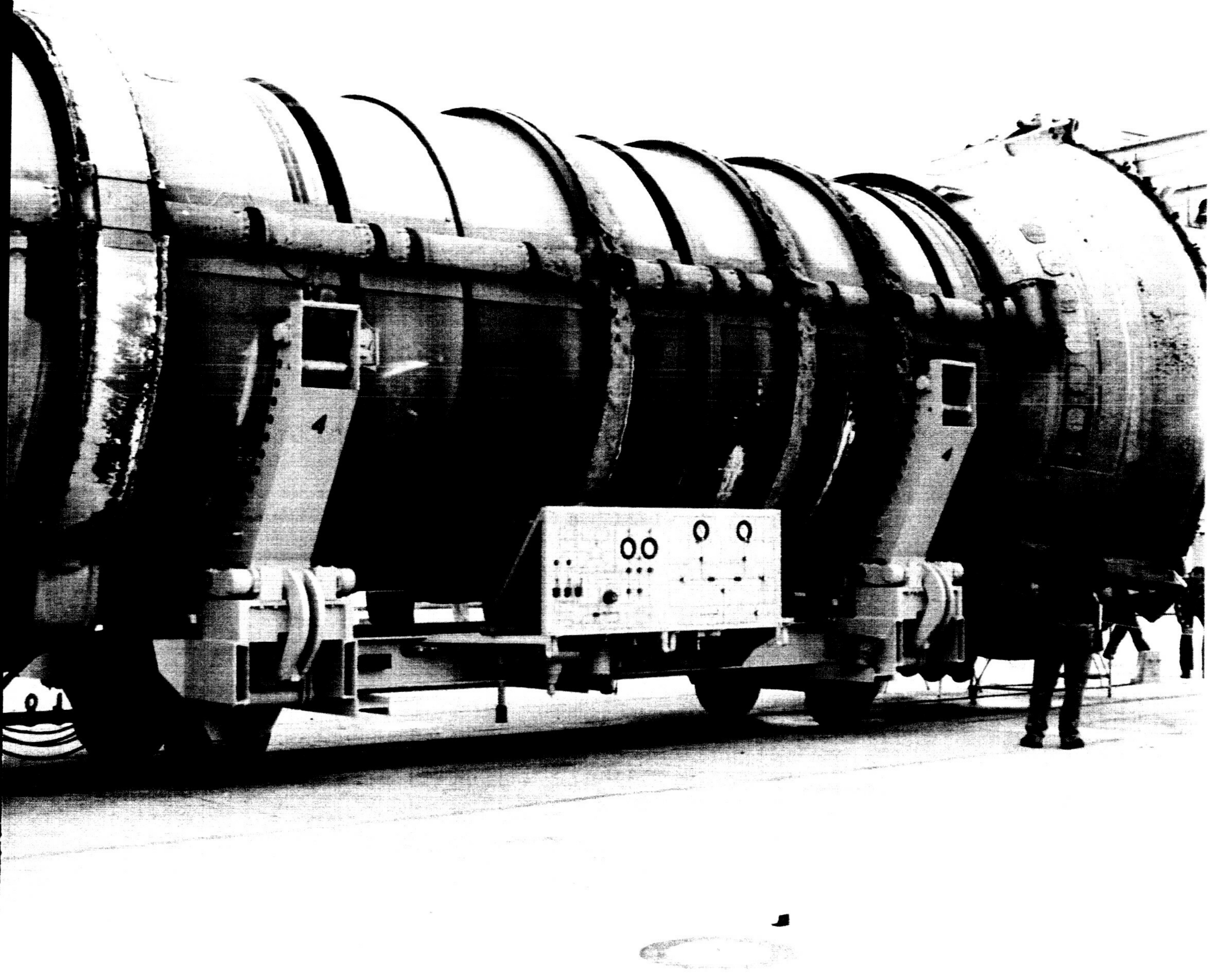


Two BSM covers on the RH frustum were bent by parachute riser entanglement after water impact



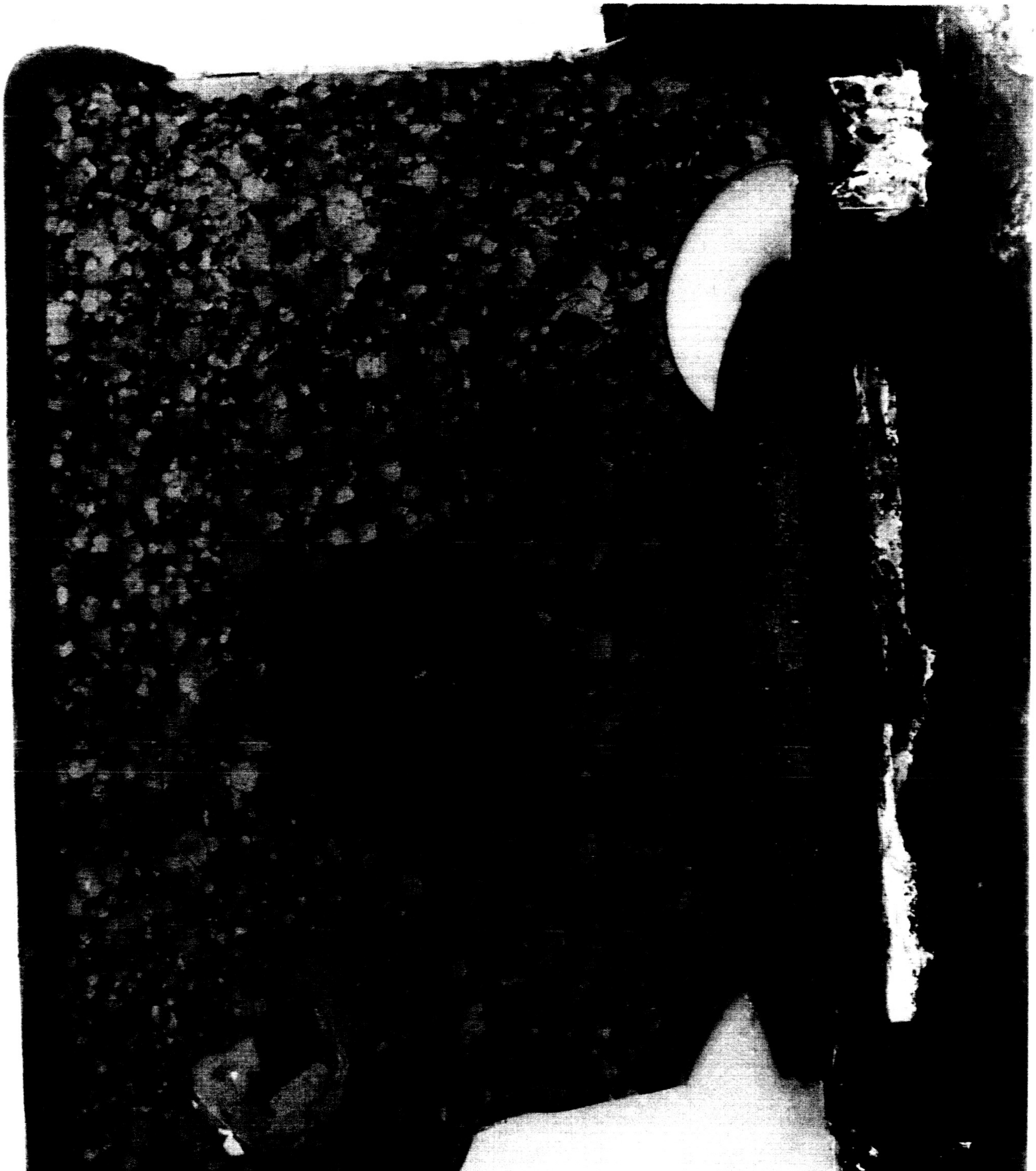
Post flight condition of the RH forward skirt. There were no MSA-2 debonds or areas of missing TPS. The parachute release ordnance had not fired at splashdown (orange containers).

Overall view of the RH solid rocket motor. The field joint protection system closeouts were generally in good condition.

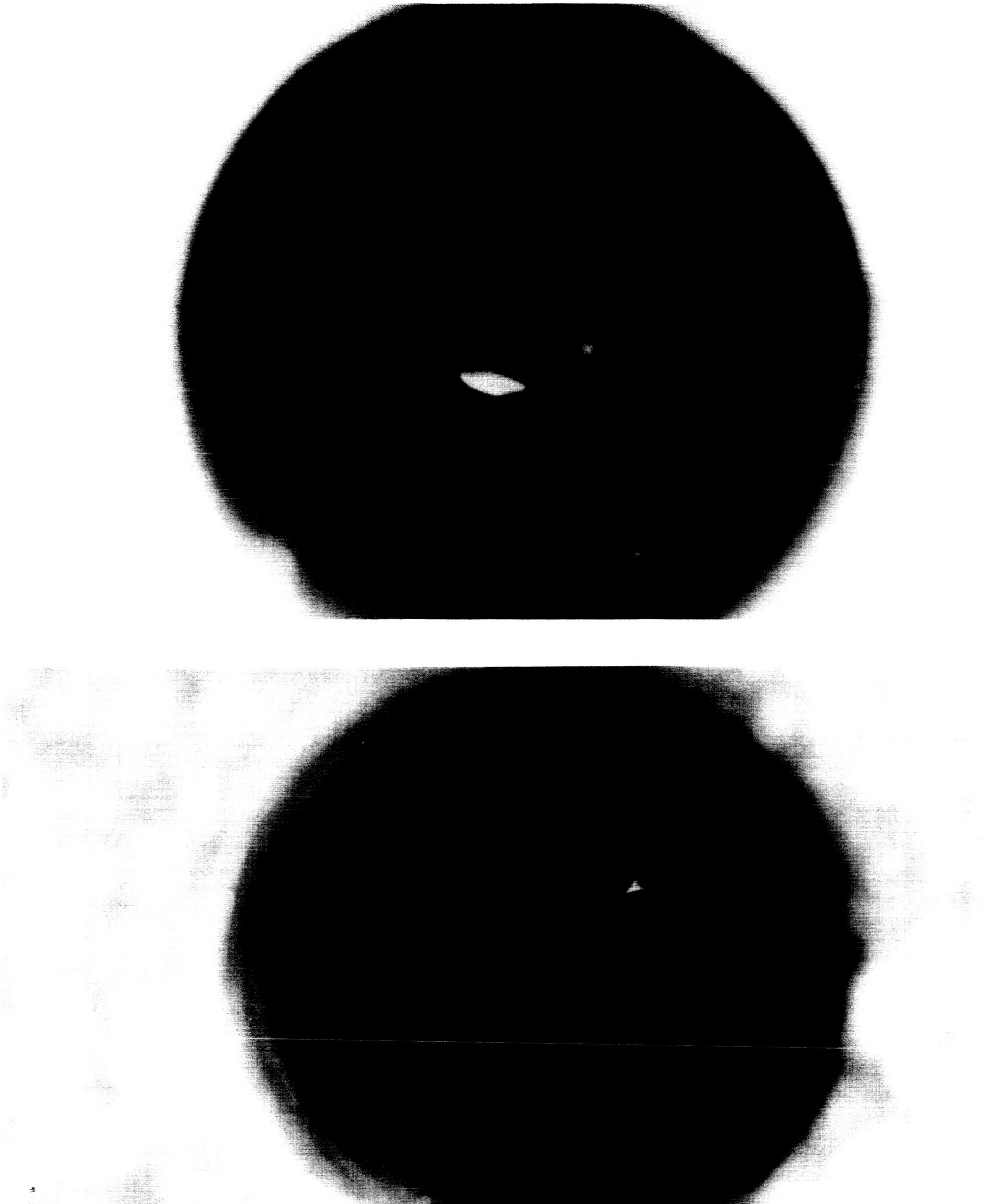


Post flight condition of the RH aft booster. The ET/SRB aft struts, ETA ring, IEA, and stiffener rings showed no unusual damage.

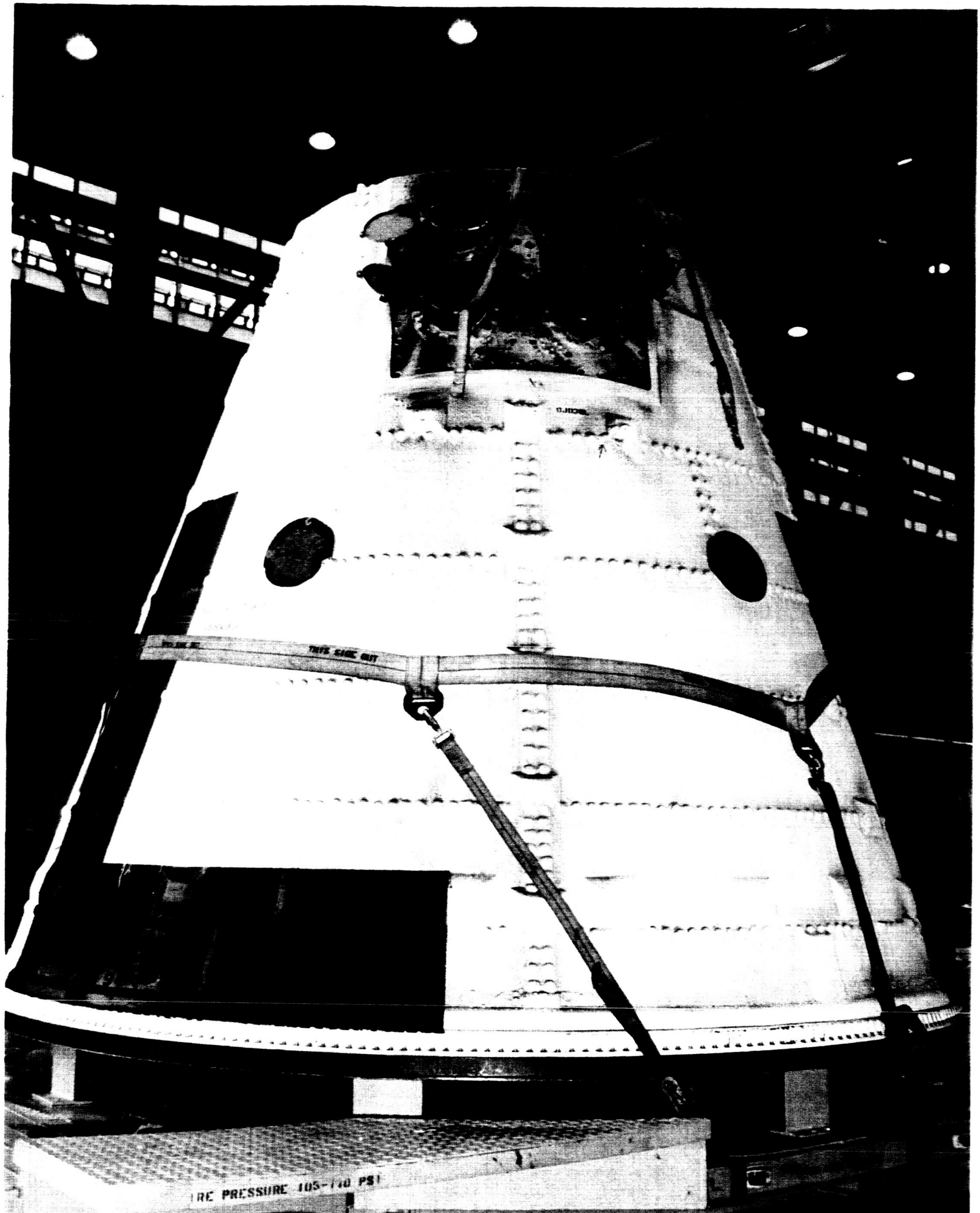
None of the K5NA protective domes on the aft side of the phenolic kick ring were missing prior to water impact



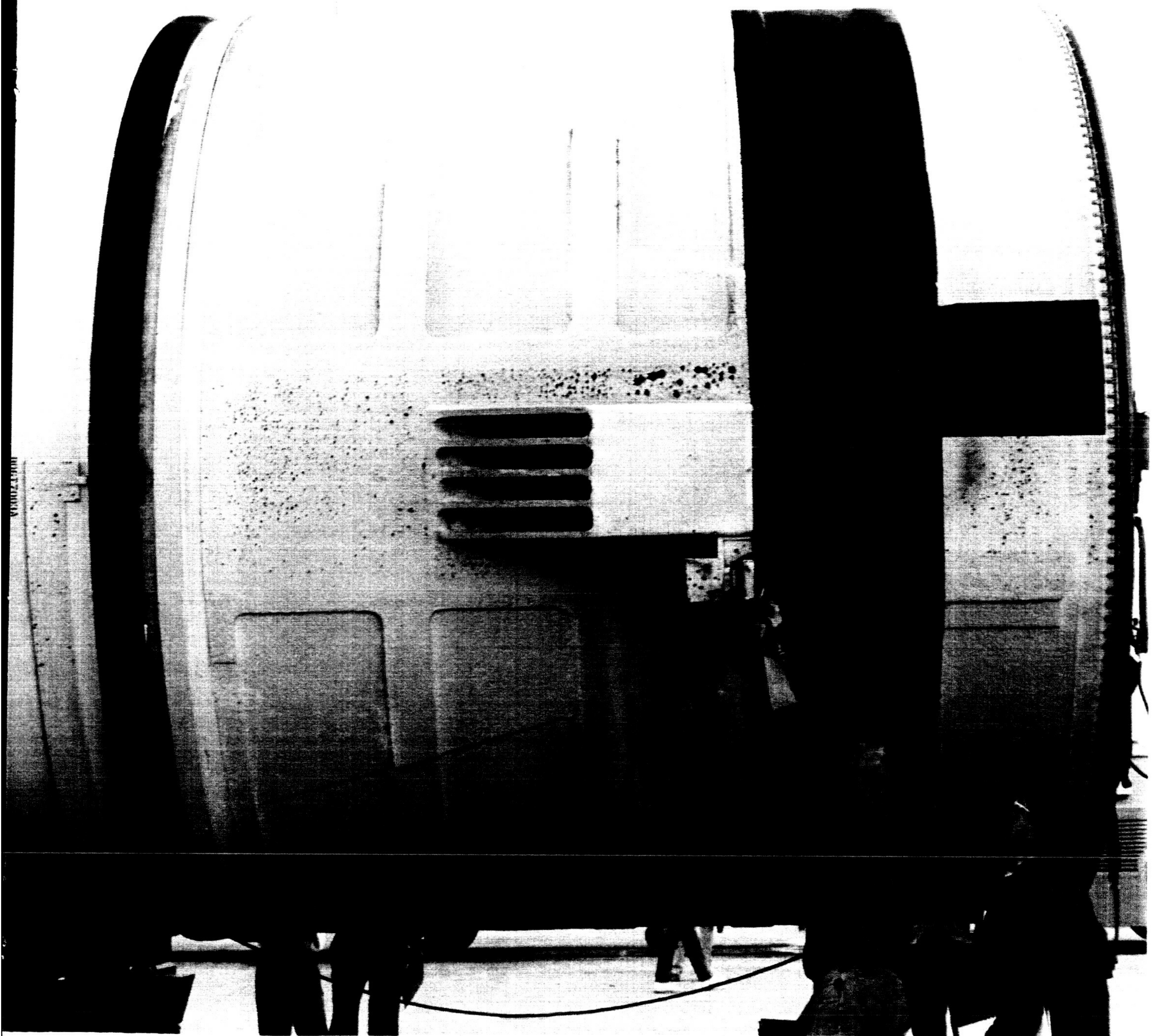
A 10"x2" portion of EPON shim material was missing from the holddown post #4 foot prior to water impact



Frangible nut halves prevented the HDP #1 and #3 DCS plungers from seating properly

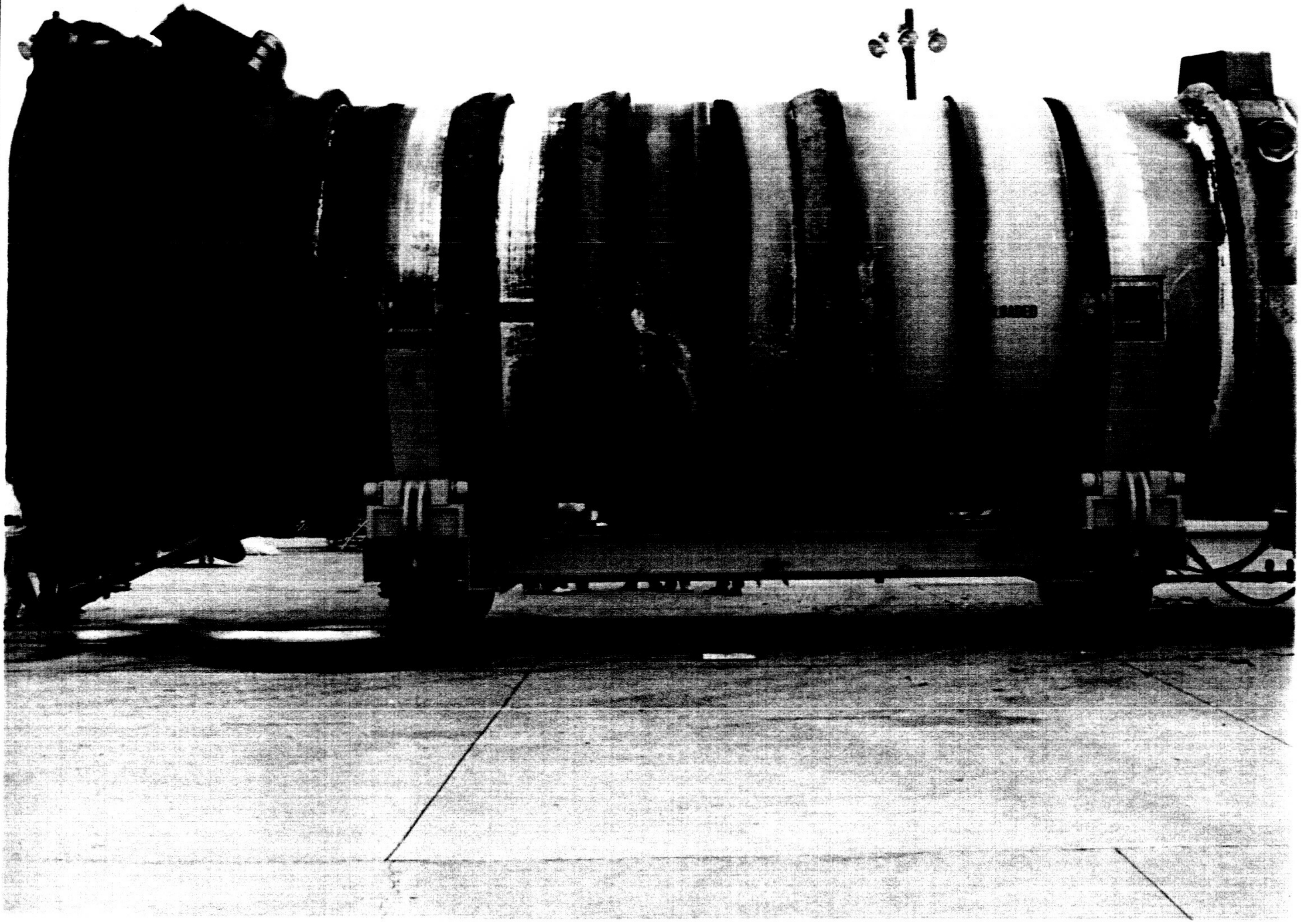


Post flight condition of the LH frustum. There were 21 MSA-2 debonds over fasteners, but no areas of missing TPS.

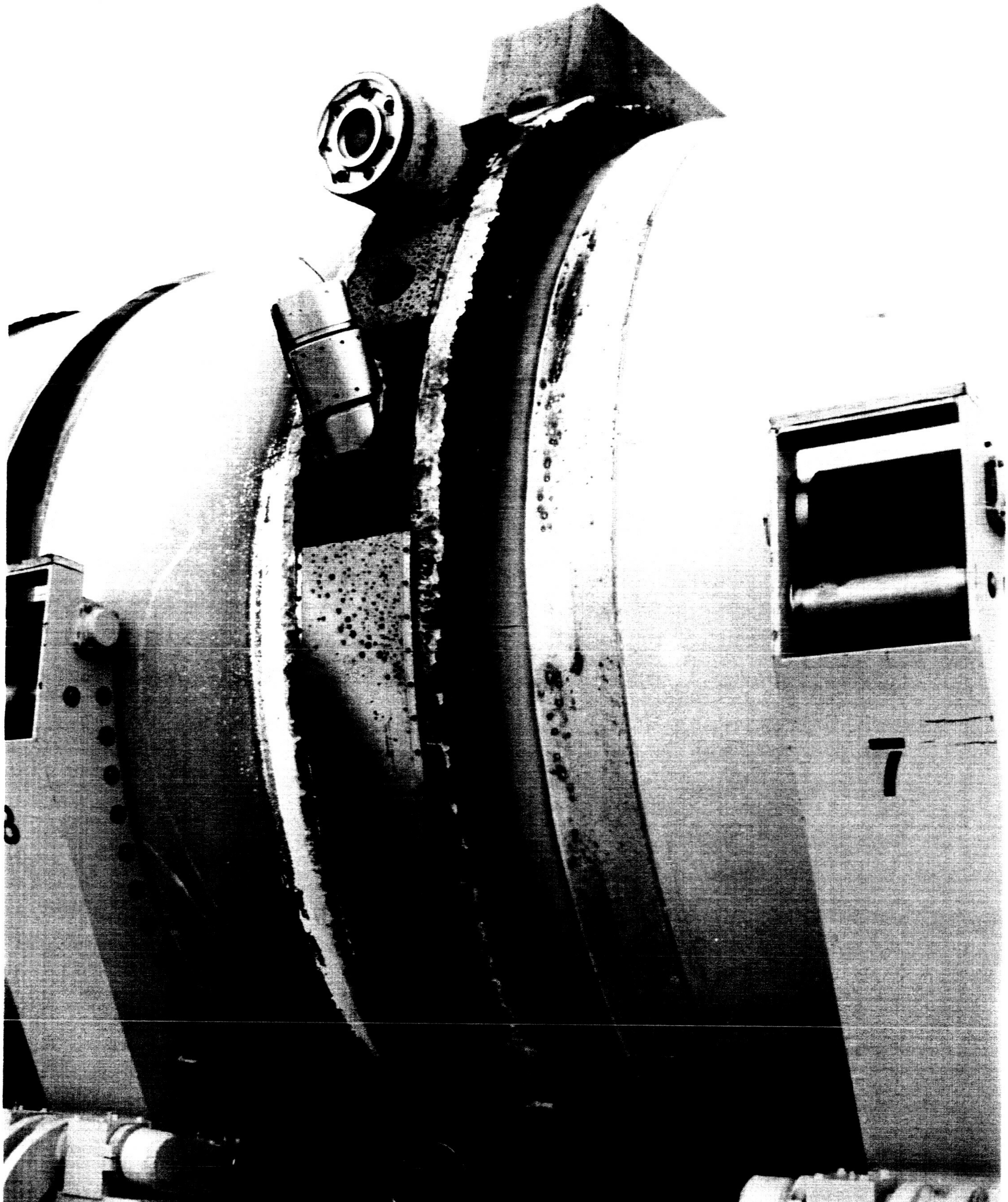


Post flight condition of the LH forward skirt. There were no MSA-2 debonds or areas of missing TPS.

The field joint protection system closeouts on the LH solid rocket motor were generally in good condition



Post flight condition of the LH aft booster. The stiffener rings appeared undamaged after water impact.



The ET/SRB struts, ETA ring, and IEA sustained no unusual damage during ascent and splashdown

A 6"x0.5" piece of sidewall shim material, which should have remained bonded to the HDP #5 shoe, was found attached to the side of the aft skirt foot after retrieval.

A 10"x1" piece of sidewall shim material, which should have remained bonded to the HDP #5 shoe, was found attached to the side of the aft skirt foot after retrieval.

9.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A detailed post landing inspection of OV-102 (Columbia) was conducted on December 10-12, 1990, at Ames-Dryden (EAFB) on Runway 22 and in the Mate/Demate Device (MDD) to identify debris impact damage, and if possible, debris sources. The TPS on the Orbiter sustained a total of 147 hits, of which 17 had a major dimension of one inch or greater. This total does not include the approximately 100 damage sites on the base heat shield.

The Orbiter lower surface had a total of 132 hits of which 15 had a major dimension of one inch or greater. A comparison of these numbers to statistics from 24 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, 27R, and 30R which had damage from known debris sources), indicates the total number of hits on the lower surface was average. Figures 11-14 show the TPS debris damage assessment for STS-35.

A cluster of 45 hits, with 6 larger then one inch, occurred just aft and inboard of the LH2 ET/Orbiter umbilical opening. Similar clusters of hits have been observed in this area on previous flights and are attributed to ice/debris impacts during ET separation and/or damage from purge barrier baggie and ice during ascent. A total of 10 hits occurred on the body flap lower surface. One of these damage sites exhibited significant thermal erosion (approximately 3/4-inch in depth) and melting of the adjacent tile coating material. The largest lower surface damage site was located on the RH chine, affected four tiles, and had a maximum depth of 1/4-inch (detail of this area is included in Figure 11).

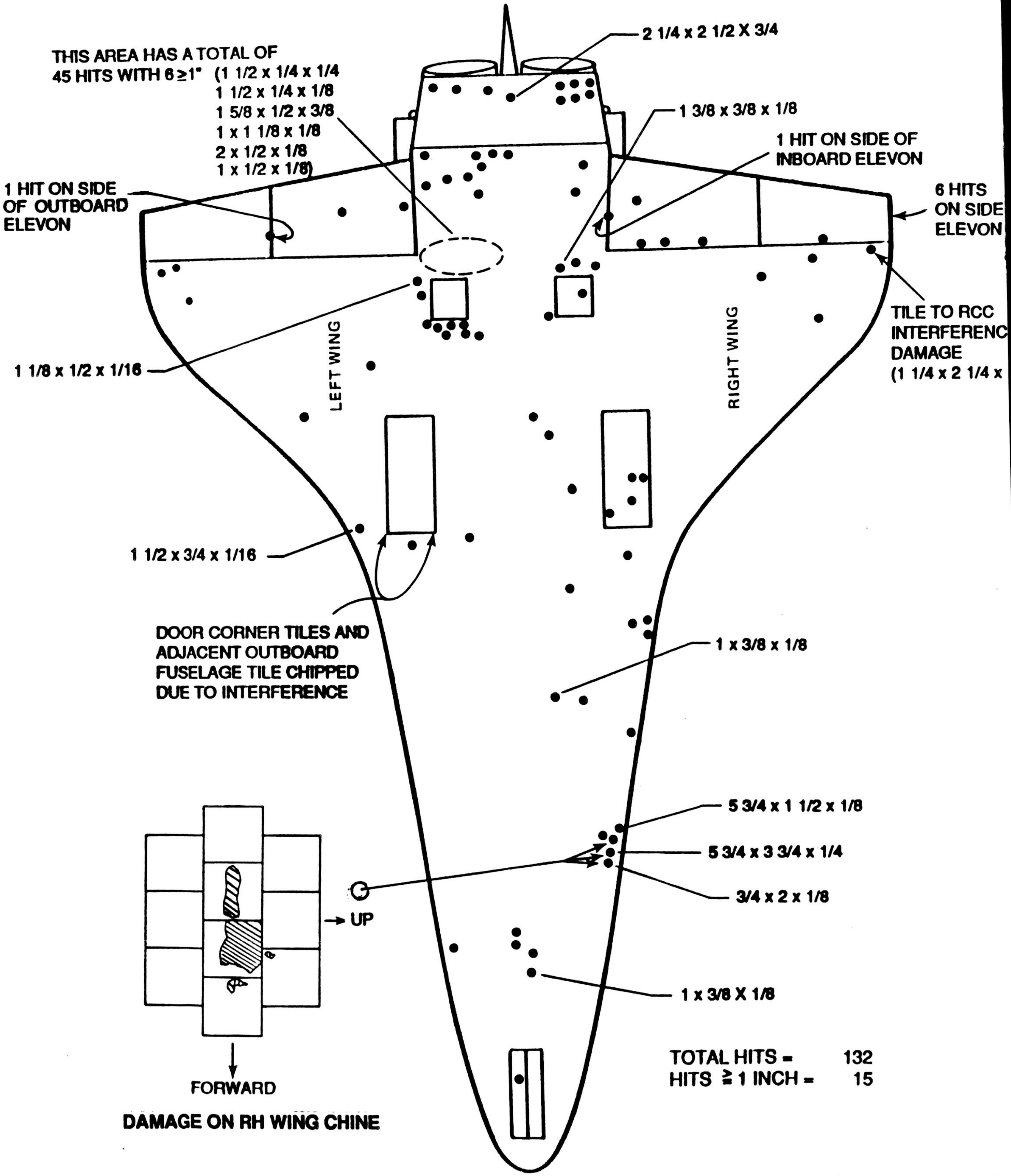
No TPS damage was attributed to material from the wheels, tires, or brakes. Material loss from the main landing gear tires was considered average for a concrete landing.

The plunger in the EO-3 (LO2) separation ordnance debris container was obstructed by a booster cartridge and failed to seat properly. This anomaly was documented on PR PYR-2-11-0091. No pieces of spent ordnance assembly were found on the runway beneath the LO2 ET/Orbiter umbilical opening. The EO-1 and EO-2 fitting separation devices appeared to have functioned properly, though the RH stop bolt on the EO-1 assembly was bent (reference PR PYR-2-11-0092). The damage to this bolt was declared an STS-35 IFA and, after extensive analysis, was dispositioned as an "Unexplained Anomaly".

Damage to the base heat shield tiles was less than average (approximately 100 sites). The body flap upper surface tiles sustained more damage than usual with several damage sites exhibiting significant depth. All three main engine closeout blankets had localized areas of peeled, frayed, and/or missing

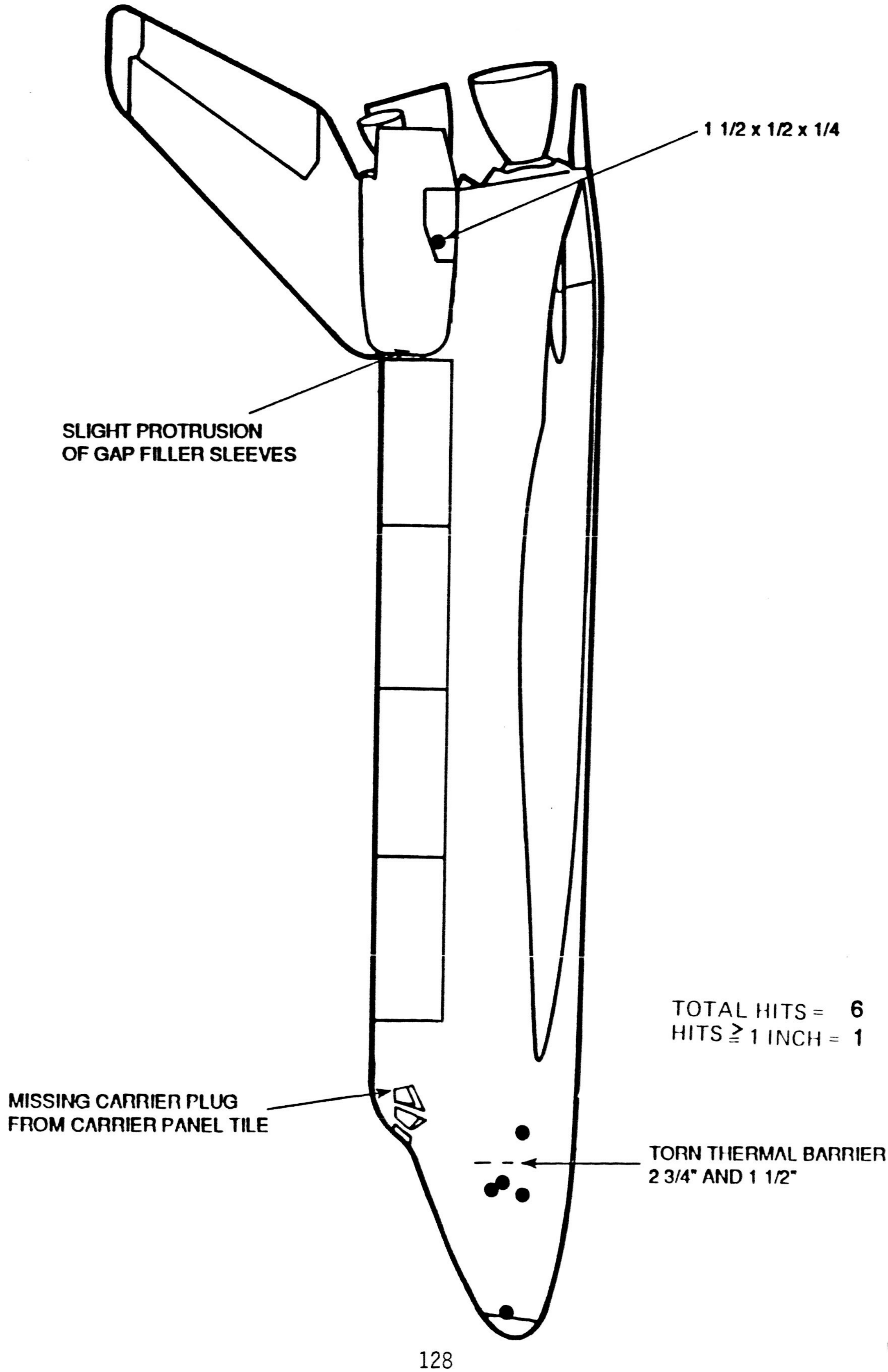
STS-35

FIGURE 11. **DEBRIS DAMAGE LOCATIONS**



STS-35

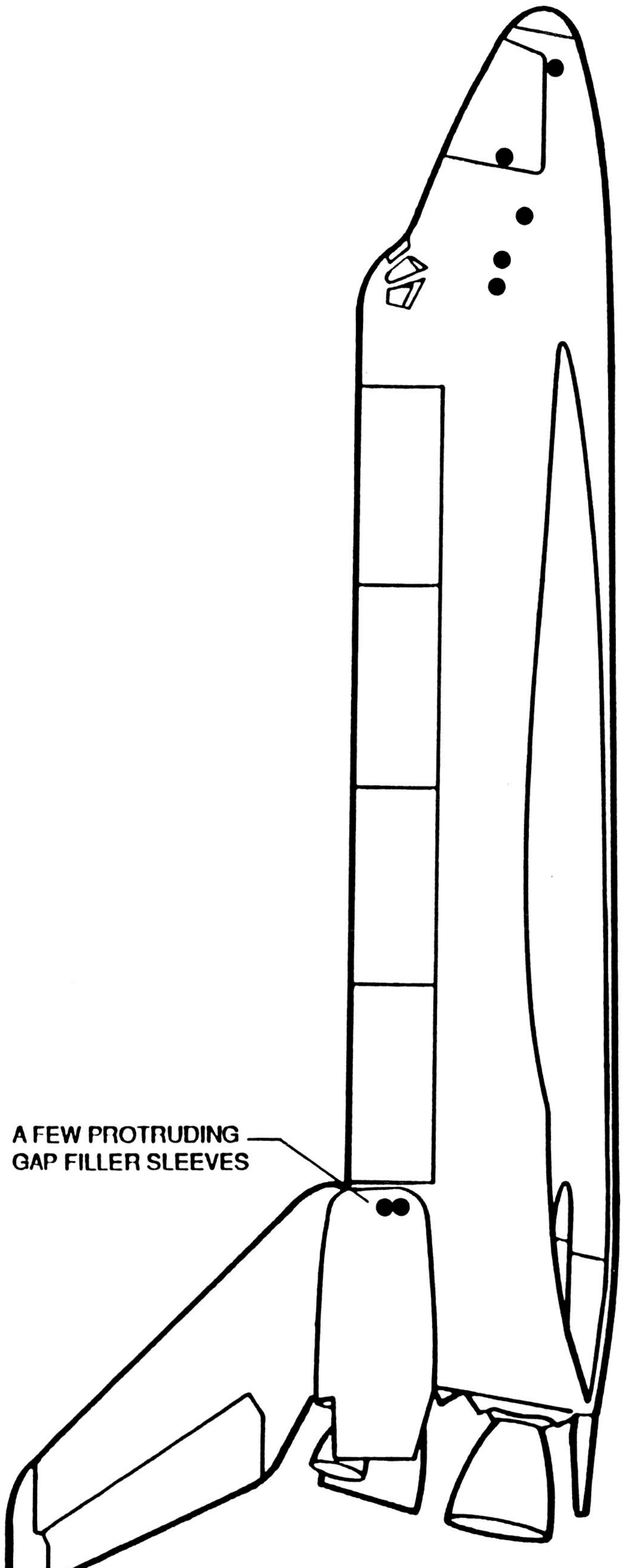
FIGURE 12. **DEBRIS DAMAGE LOCATIONS**



EGG/V 088

STS-35

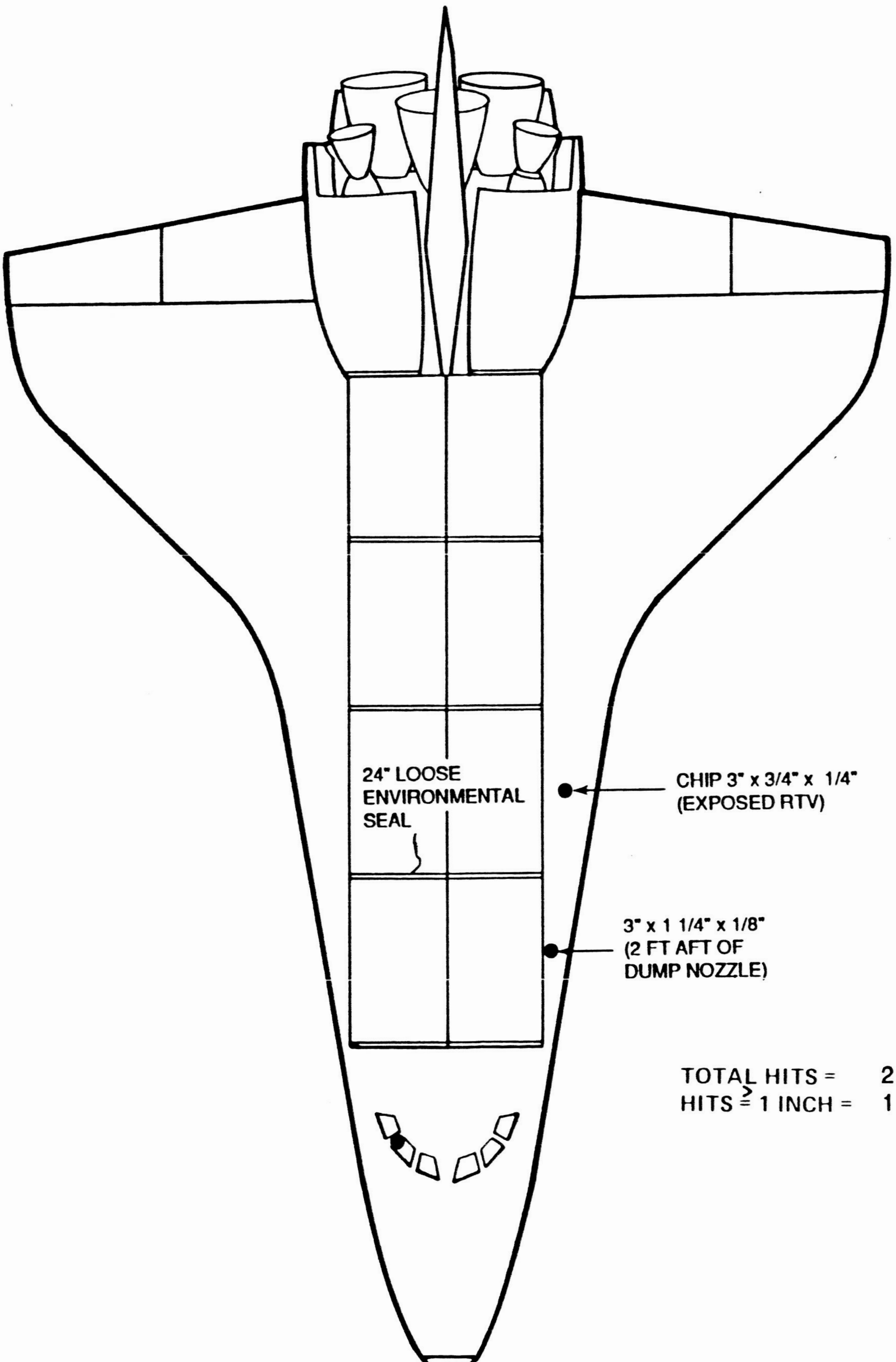
FIGURE 13. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = 7
HITS $\geq$ 1 INCH = 0

STS-35

FIGURE 14. **DEBRIS DAMAGE LOCATIONS**



EGG/V 088C

material. The SSME #1 blanket was damaged from 5:30 to 6:30 o'clock; SSME #2 blanket from 1:30 to 4:00 o'clock; and SSME #3 blanket from 8:30 to 10:30 o'clock.

Water dripped from the RH rudder speed brake (RSB) split line thermal barrier shortly after landing. This water originated from a thin layer of melting clear ice on a 3-inch long segment of the thermal barrier near the trailing edge of the RSB. This phenomenon has never been observed before.

Several small pieces of gap filler sleeving material were protruding slightly on the leading edges of both the RH and LH OMS pods. No detectable damage to adjacent tiles resulted from these gap fillers. The overall condition of the OMS pods was good.

The white tiles on the upper Orbiter surfaces showed the usual amount of degradation. The majority of this damage was located immediately forward and aft of the elevon hinge lines and cannot be attributed to debris impacts.

Typical white streaks were present on RH wing leading edge RCC panel #17, T-seal #6, and T-seal #11. A black streak was present on the LH wing leading edge panel #8. Samples of these streaks were taken for laboratory analysis (Fig 15-16).

A piece of environmental seal material, approximately 24 inches long, loosely hung from the expansion joint between the first and second sections of the RH payload bay door.

An impact crater 0.0682" in diameter by 0.0109" deep was reported on Orbiter window #1 (reference PR TES-2-11-0053). This damage was most likely caused by orbital debris. A ceramic insert was missing from a carrier panel tile on the frame around window #1. Orbiter windows #3 and #4 were moderately hazed with some minor streaking. Windows #2 and #5 were lightly hazed. Wipes were taken from all windows for laboratory analysis.

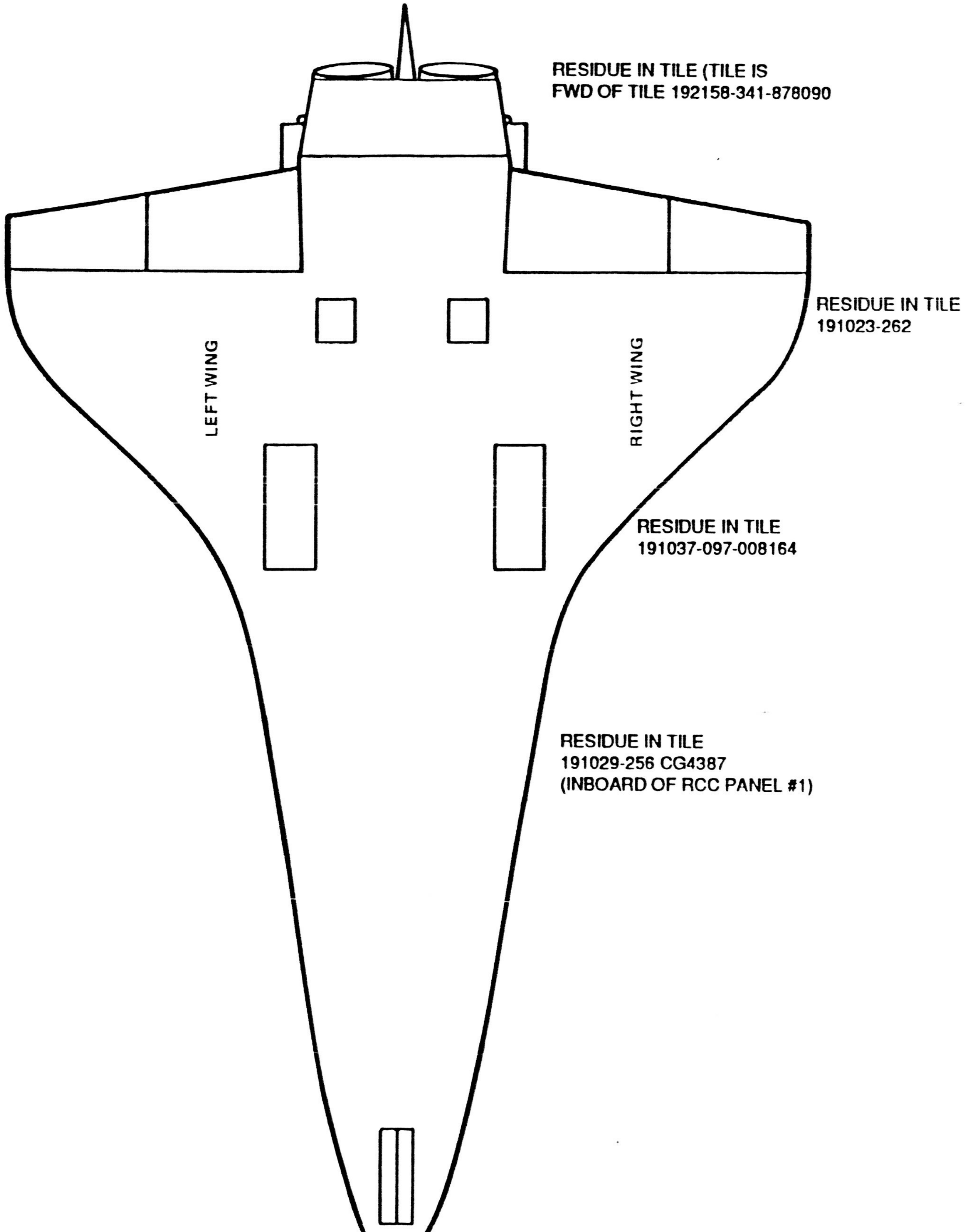
The KSC Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas. Sixteen minutes after landing, the Orbiter nosecap RCC was 177 degrees F, the RH wing leading edge RCC panel #9 was 85 degrees F, and the RH wing panel #17 was 76 degrees F (Figure 17).

Runway 17L was inspected by the Debris Team on December 10, 1990, and all potentially damaging debris was removed. Runway 22 was inspected and swept by Air Force personnel. Both runways were found to be in good condition.

The post landing inspection of Runway 22 was performed approximately 1/2 hour after landing. No flight hardware was found.

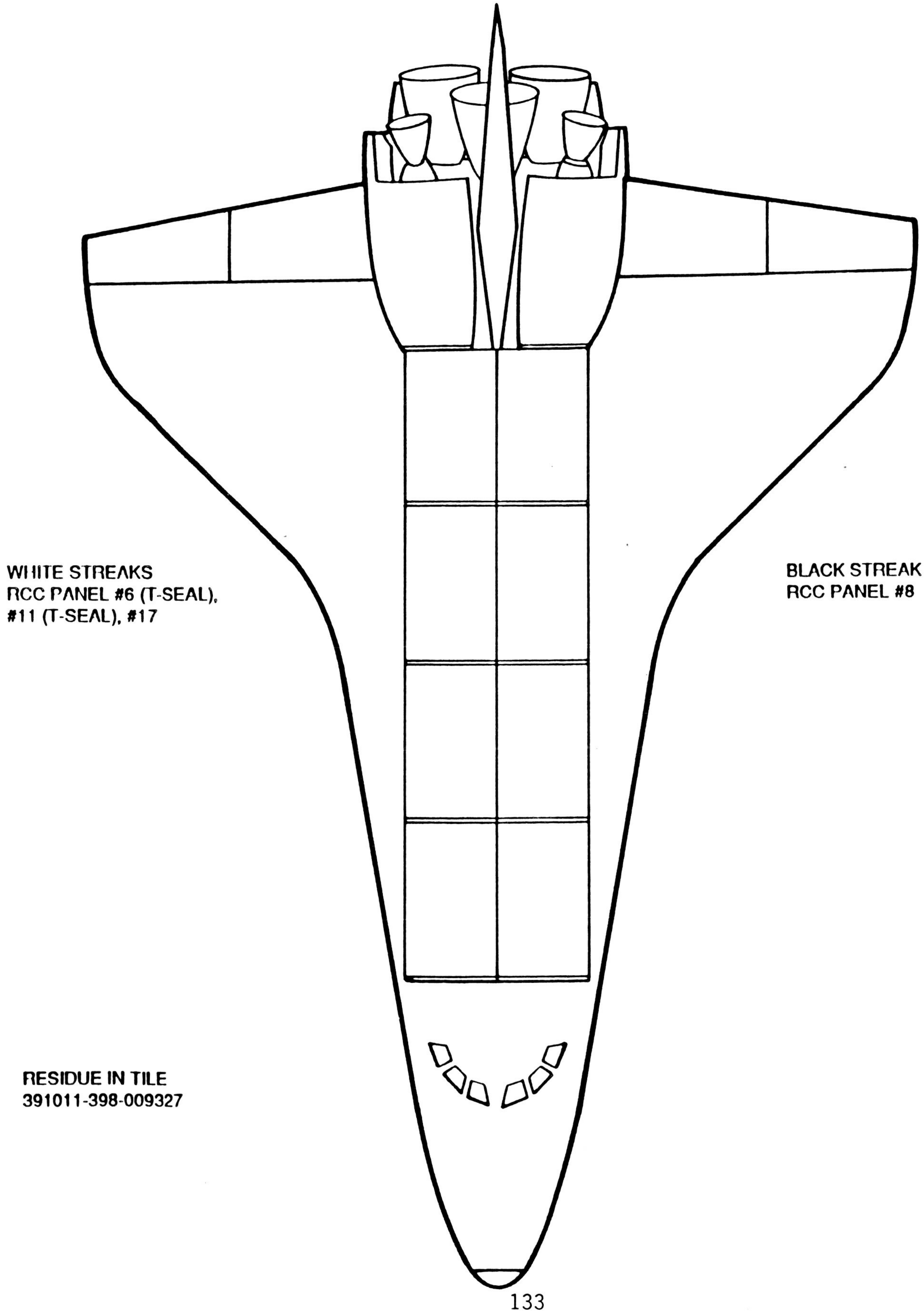
STS-35

FIGURE 15. **DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS**



STS-35

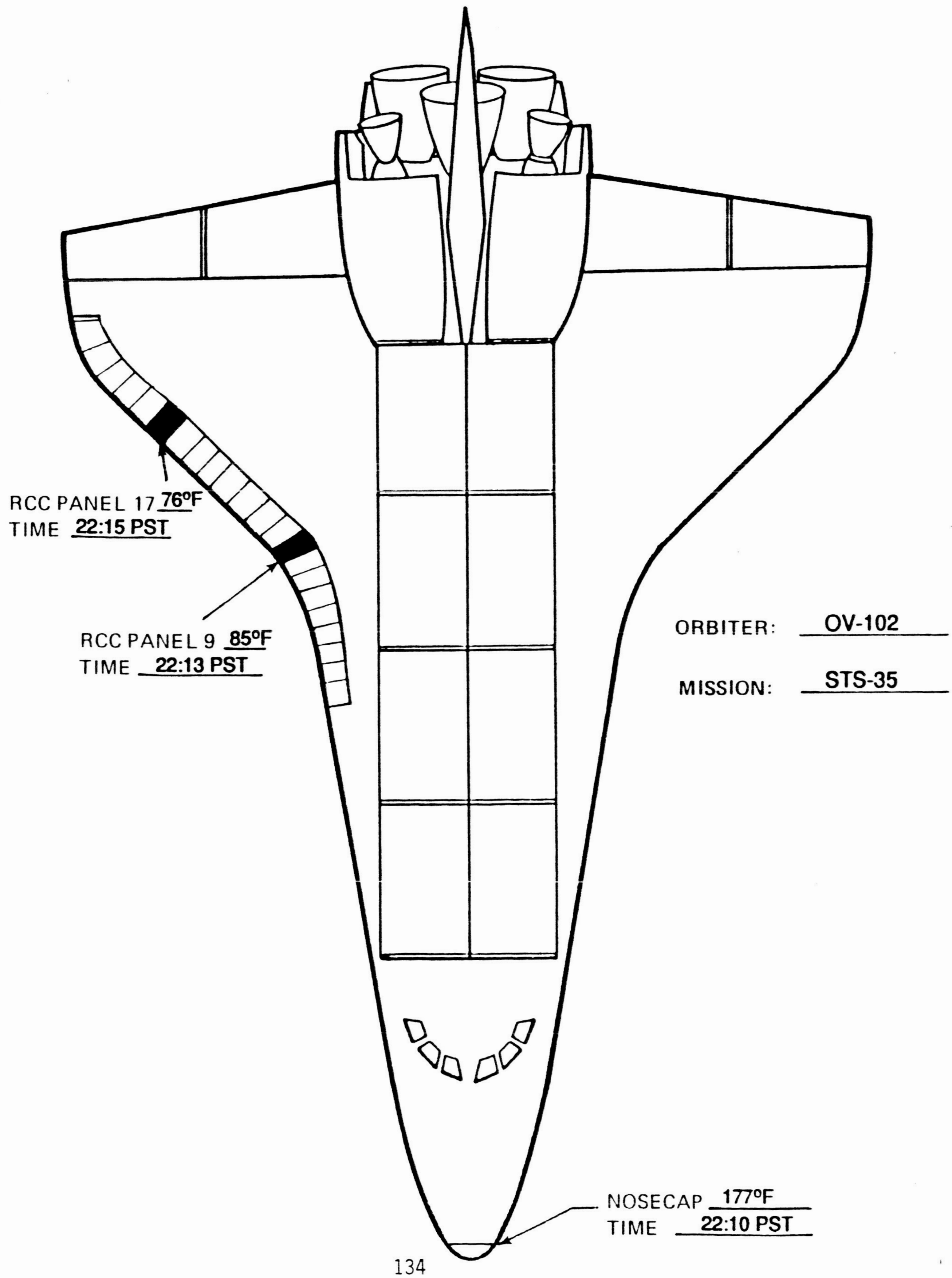
FIGURE 16. **DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS**



EGG/V 088

STS-35

FIGURE 17. **TEMPERATURE MEASUREMENTS**



In summary, the total number of lower surface Orbiter TPS debris hits was average when compared to previous flights, as shown in the comparison chart (Figure 18-20). Other than the cluster of hits aft of the LH2 ET/Orbiter umbilical area, the distribution of hits on the Orbiter does not point to a single source for ascent debris, but indicates a shedding of ice and TPS debris from random sources.

Orbiter Post Landing Anomalies are listed in Section 11.4.

FIGURE 18. STS-35 DEBRIS DAMAGE ASSESSMENT SUMMARY

	Hits > or = 1"	Total Hits
Lower Surface	15	132
Upper Surface	1	2
Right Side	0	5
Left Side	0	5
Right OMS Pod	0	2
Left OMS Pod	1	1
TOTALS	17	147

COMPARISON TABLE

STS-6	36	120
STS-7	48	253
STS-8	7	56
STS-9 (41-A)	14	58
STS-11 (41-B)	34	63
STS-13 (41-C)	8	36
STS-14 (41-D)	30	111
STS-17 (41-G)	36	154
STS-19 (51-A)	20	87
STS-20 (51-C)	28	81
STS-23 (51-D)	46	152
STS-24 (51-B)	63	140
STS-25 (51-G)	144	315
STS-26 (51-F)	226	553
STS-27 (51-I)	33	141
STS-28 (51-J)	17	111
STS-30 (61-A)	34	183
STS-31 (61-B)	55	257
STS-32 (61-C)	39	193
STS-26R	55	411
STS-27R	298	707
STS-29R	23	132
STS-30R	56	151
STS-28R	20	76
STS-34	18	53
STS-33R	21	118
STS-32R	15	120
STS-36	20	62
STS-31R	14	63
STS-41	16	76
STS-38	8	81
STS-35	17	147

FIGURE 19.

COMPARISON TABLE

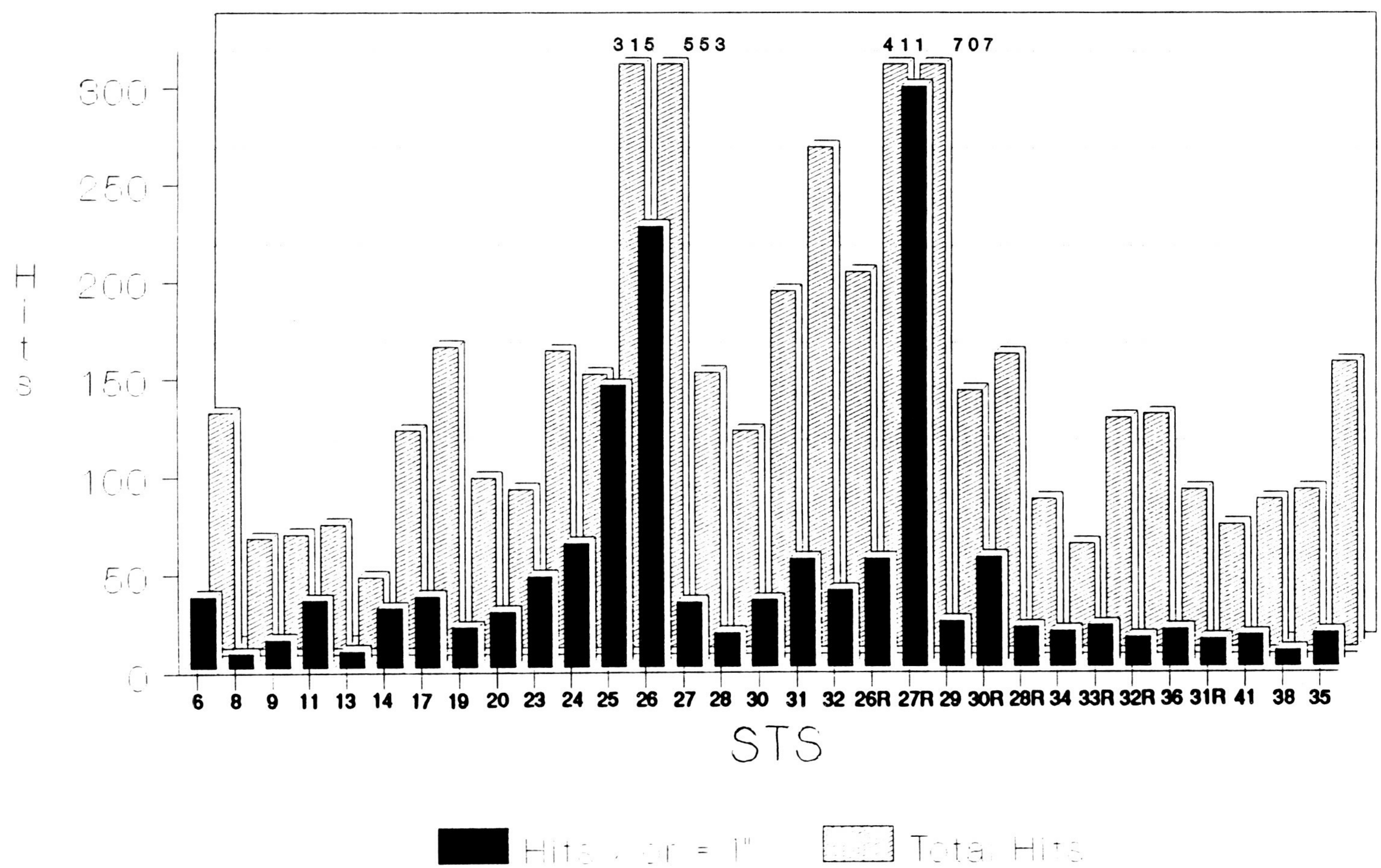
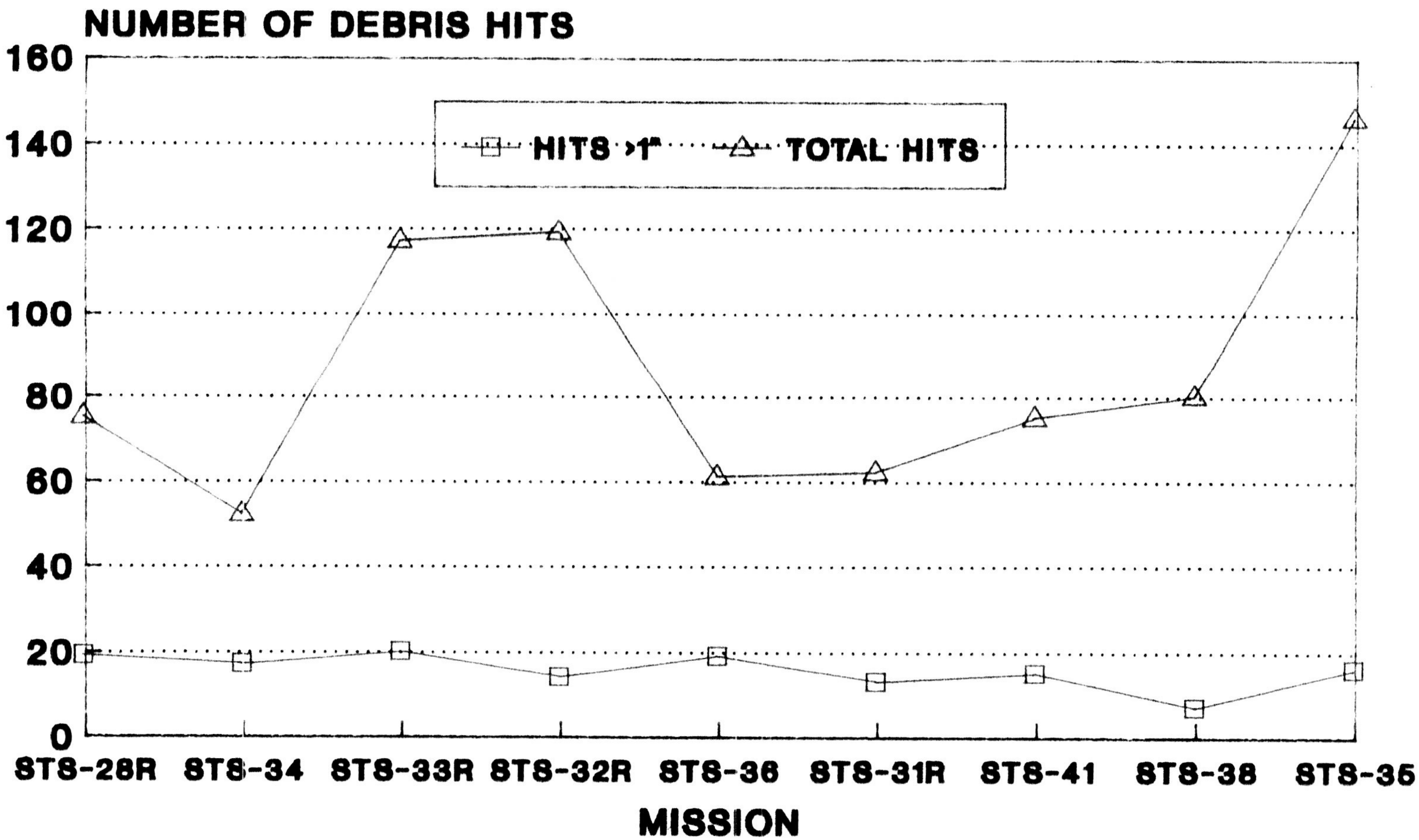
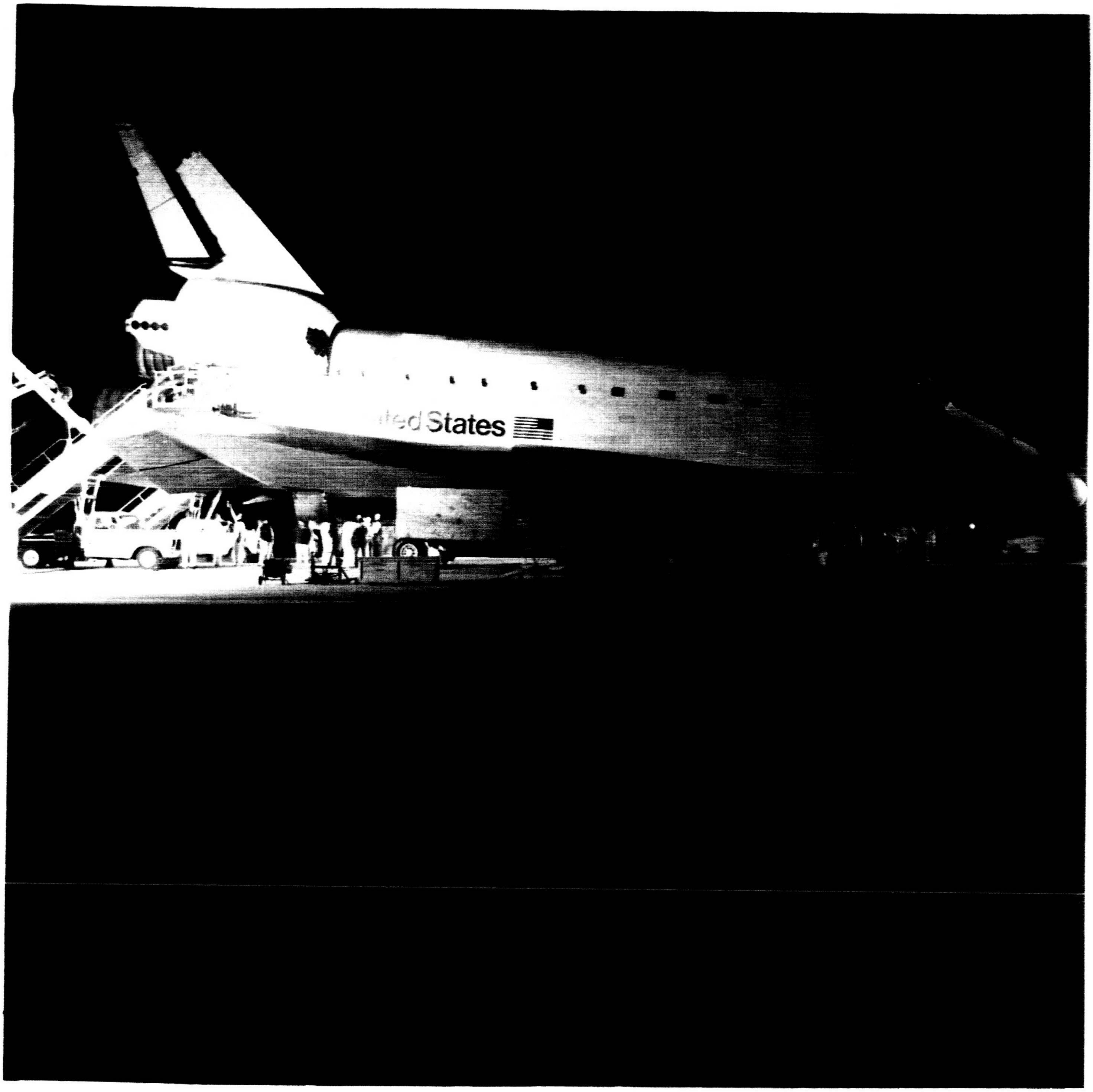


FIGURE 20.

ORBITER TPS DEBRIS DAMAGE
STS-28R THROUGH STS-35



Overall view of OV-102 left side after landing



Overall view of OV-102 right side after landing

Overall view of OV-102 aft end/SSME's after landing

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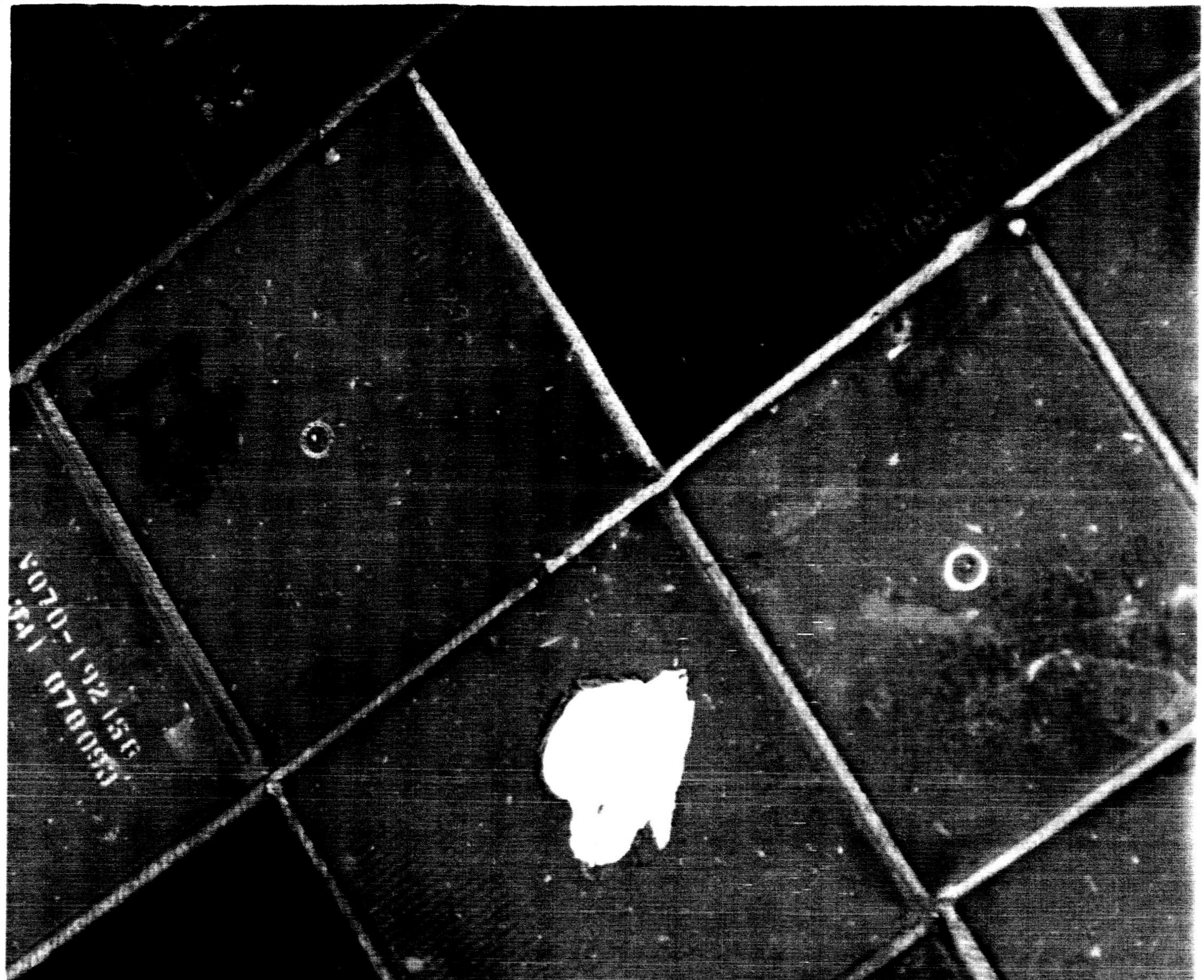
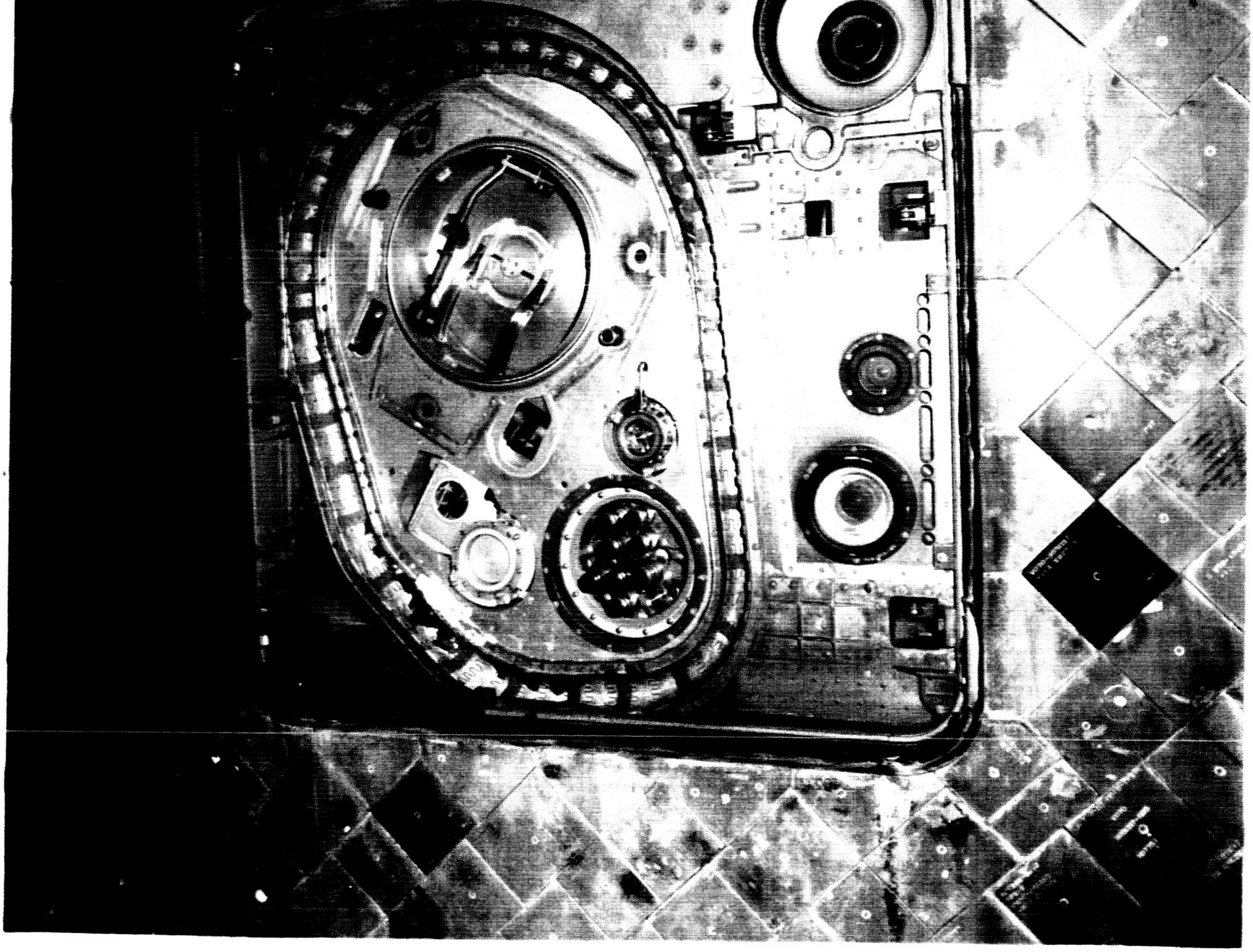
COLOR PHOTOGRAPH



One tile damage site on the lower surface exhibited significant thermal erosion to a depth of 3/4-inch and melting of the adjacent coating material.

The largest lower surface tile damage site was located on the RH chine, affected 4 tiles, and had a maximum depth of 1/4-inch



Overall view of the LH2 ET/ORB umbilical. The EO-2 separation ordnance debris plunger was seated properly.

Overall view of the LO2 ET/ORB umbilical. The plunger in the EO-3 separation debris container had not seated properly.

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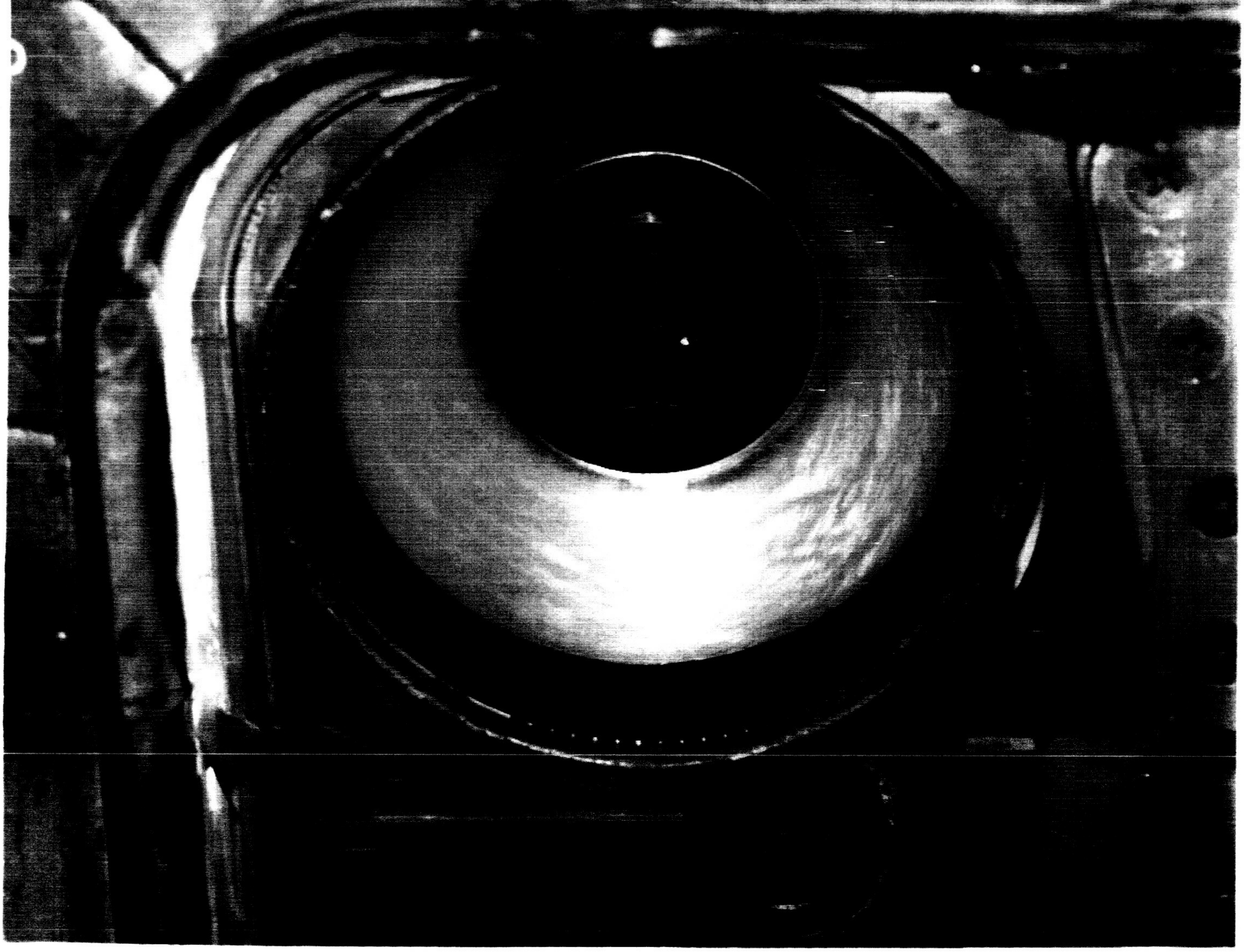
COLOR PHOTOGRAPH

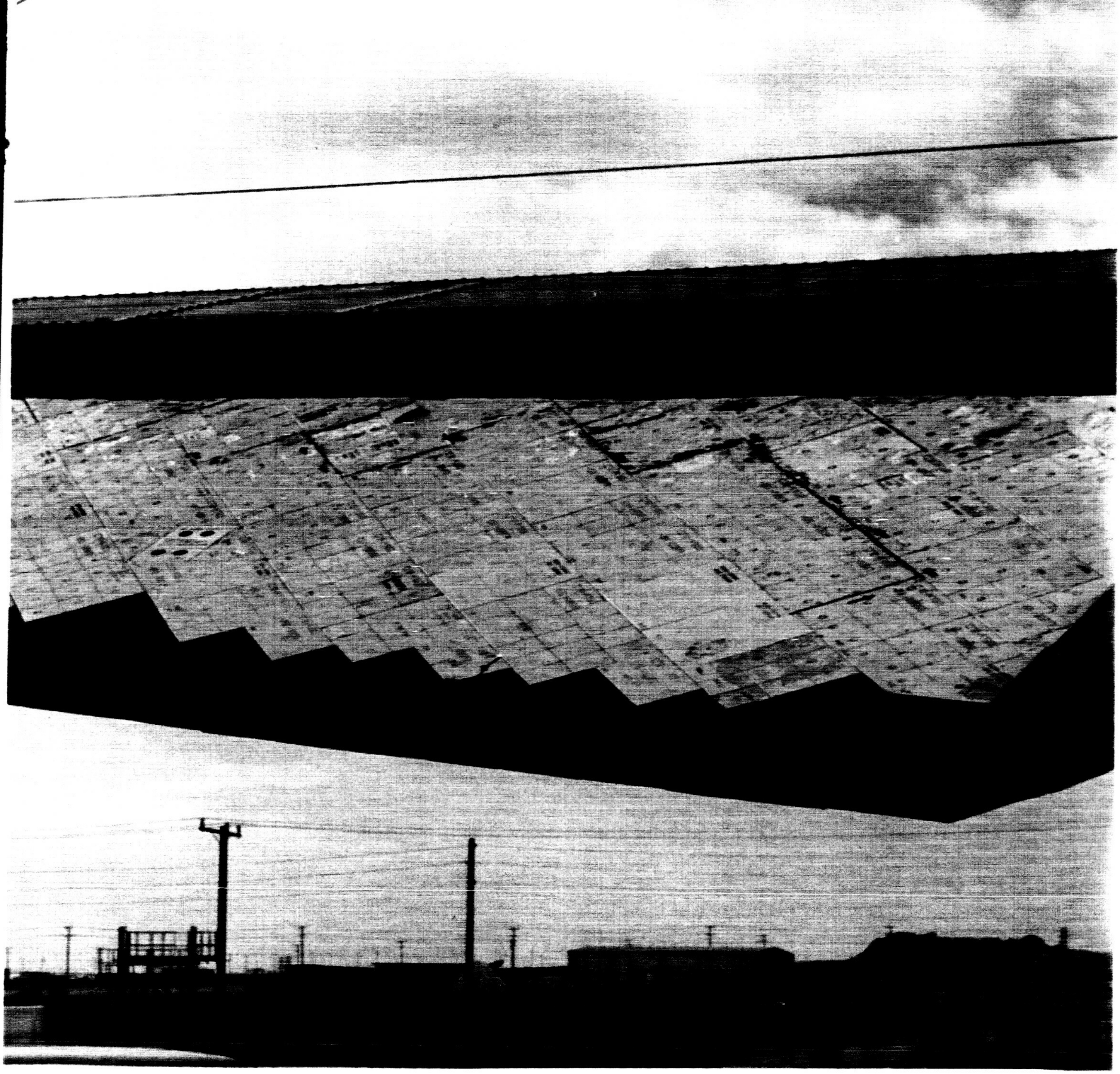


The plunger in the LO2 ET/ORB umbilical separation debris container had been obstructed by a booster cartridge

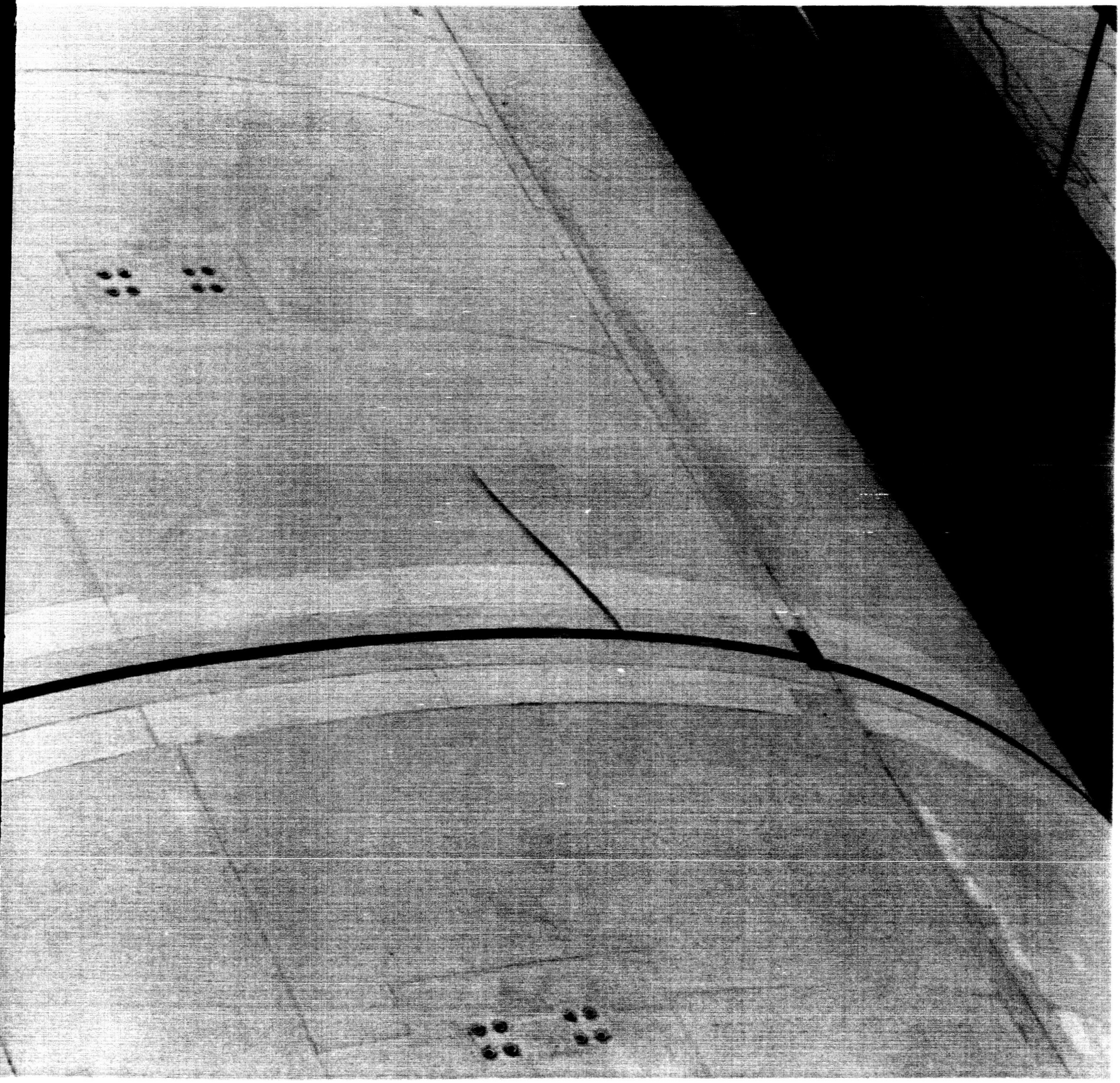
Obstruction of EO-2/3 separation ordnance debris plungers
by booster cartridges/ordnance fragments occurs frequently.

Damage to the base heat shield tiles was less than average. All three SSME closeout blankets had localized areas of peeled, frayed, and/or missing material.

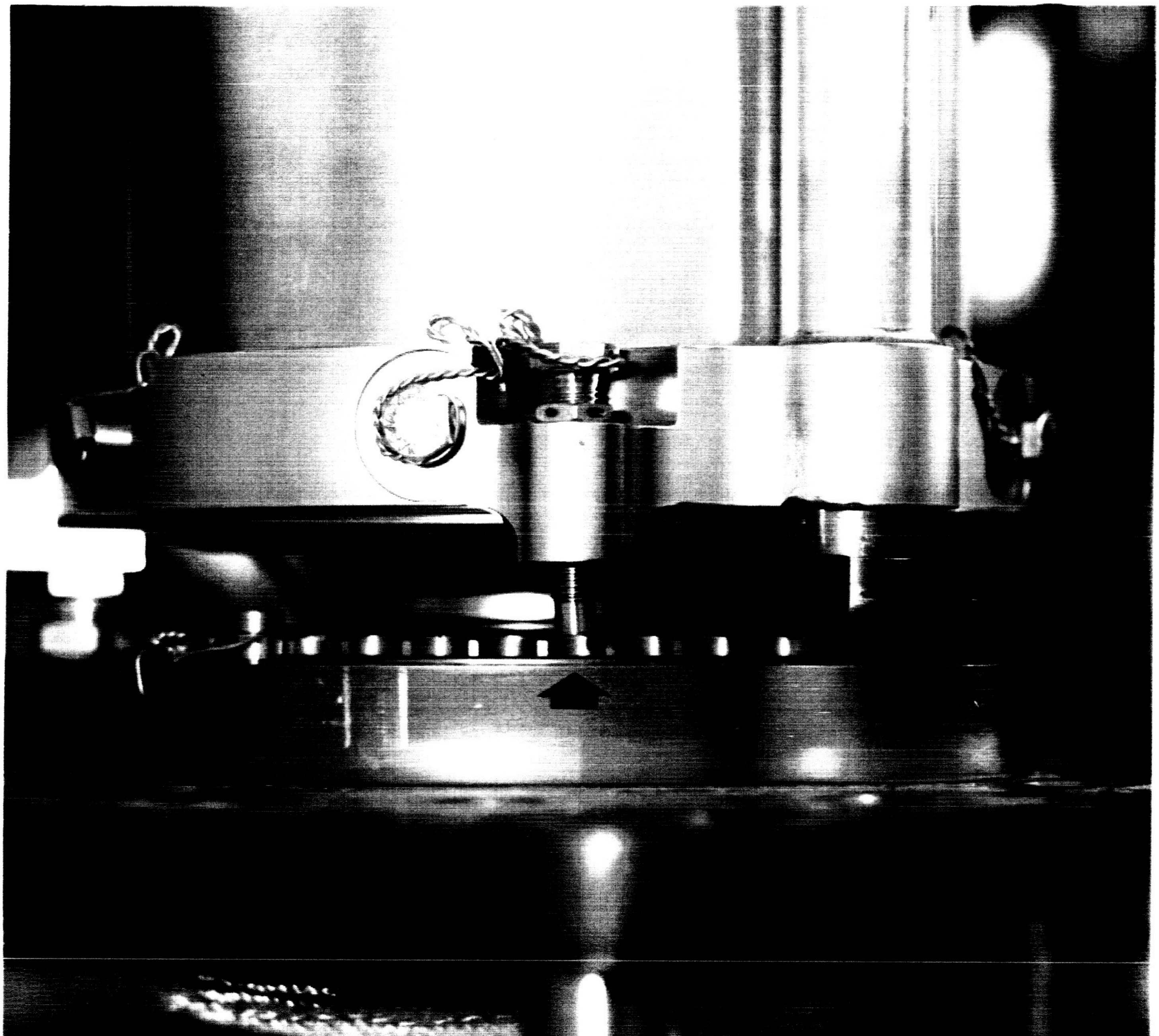
Body flap upper surface tiles sustained more damage than usual with several damage sites exhibiting significant depth



SSME ignition vibration/acoustics during launch caused pieces of tile material to shake loose from the elevon upper surfaces



A 24-inch piece of seal material hung loosely from the joint between the first/second sections of the RH payload bay door



The EO-1 forward attach point separation device appeared to operate properly, though the RH stop bolt was bent

10.0 DEBRIS SAMPLE LAB REPORTS

A total of 17 samples were obtained from Orbiter OV-102 during the STS-35 post-landing debris assessment at Ames-Dryden Flight Research Facility, California (Figures 15-16). The seventeen submitted samples consisted of 8 Orbiter window wipes, 2 samples from the ET/ORB umbilical area, 2 wing leading edge RCC samples 1-(RH) 1-(LH), and 5 tile samples. A reference sample of SRB slag was also submitted due to similar appearance of the debris from tile 197007-146. The samples were analyzed by the NASA-KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. The specific elemental analysis is shown in the appended MAB reports. Debris analysis involves the placing and correlating of particles with respect to composition, availability and thermal (mission) effects. Debris samples and analyses are provided by Orbiter location in the following summaries.

Orbiter Windows

Results of the window wipe chemical analysis indicates the presence of the following materials:

1. Metallic particles
2. Rust and paint
3. Dust and salt
4. Muscovite
5. RTV and insulation glass fibers
6. Organics
7. Cerium-Lanthanum compound

Debris analysis provides the following correlations:

1. Metallic particles (cadmium, carbon steel, brass, stainless steel) are common to the landing site and SRB/BSM exhaust, but are not considered a debris concern in this quantity (micrometer), and have not demonstrated a known debris effect.
2. Rust is common to SRB/BSM residue and the landing site, paint is used on flight element, ground support equipment (GSE) and facility.
3. Dust and salt are landing site products.
4. Muscovite is a naturally-occurring landing site product.
5. RTV and insulation glass fibers originate from Orbiter thermal protection system (TPS).
6. Organic materials are probably insect/animal remains and deposits, or tile waterproofing agents.
7. Cerium-Lanthanum compound is a residue of Orbiter window cleaning compound.

ET-Orbiter umbilicals

Chemical analysis of samples from the ET/Orbiter umbilicals revealed the following materials:

1. Metallic particles
2. Rust and paint
3. Silicon-rich materials
4. Glass fiber
5. Organics

Debris analysis provides the following correlations:

1. Metallic particles (Aluminum and stainless steel) are common to the landing site and SRB/BSM exhaust residue, but are not considered a debris concern in this size (micrometer), and have not demonstrated a known debris effect.
2. Rust is common to SRB/BSM exhaust residue and the landing site, paint is used on flight element, ground support equipment (GSE) and facility.
3. Silicon-rich materials probably originated from high temperature insulation (TPS).
4. Glass fiber is a high temperature Orbiter insulation.
5. Organics are indicative of umbilical closeout materials.

Orbiter wing RCC panels

Results of the wing leading edge RCC samples indicated the presence of the following materials:

1. Metallic particles
2. RTV, black and white silicon-rich materials
3. Organics

Debris analysis provides the following correlations:

1. Metallic particles (brass and carbon steel) are common to SRB/BSM exhaust residue and the landing site, but are not considered a debris concern in this quantity (micrometer) and have not demonstrated a known debris effect.
2. RTV, black and white silicon-rich materials originate from Orbiter thermal protection system (TPS).
3. Organics were not analyzed due to the small amount of the sample.

Orbiter Tile

Results of the tile sample chemical analysis revealed the presence of the following materials:

1. Silicon-rich TPS materials (black and white)
2. Metallic particles
3. Embedded debris - "facility" welding slag

Debris analysis provides the following correlations:

1. Silicon-rich TPS materials (black and white) are used on the Orbiter thermal protection system (TPS).
2. Metallic particles (rustic and aluminum) are small and do not provide positive source identification.
3. Embedded debris was found to be ferrous material - as facility type welding slag with a trace of RTV (Orbiter TPS).

SRB slag

The reference sample of SRB slag provided no evidence for a chemical comparison to the embedded tile debris. SRB slag was found to be corundum (Aluminum oxide).

Conclusions

The STS-35 mission, as evidenced by the debris analysis report, was successful in minimizing damage from debris. This is also shown to be true by the chemical analyses that was performed on post-flight samples.

The Orbiter window sampling provided results that indicate exposure to SRB/BSM exhaust residue, thermal protection system materials, and landing site products. The presence of a variety of metallic particles demonstrates window exposure to differing environments; however, the absence of window debris damage supports analysis that metallic particulate is not a debris threat in this area. Also noted is the presence of residual window cleaning compound, similar to that of STS-33R.

Samples from the ET/Orbiter umbilical area indicated closeout-type materials, landing site products, Orbiter TPS materials, and paint. This variety of residues demonstrates the umbilical's ability to retain debris, although no debris damage was noted.

The Orbiter wing RCC sampling indicated metallic particles, thermal protection system materials and organics. This residual variety indicates thermal protection system deposits. No RCC debris damage was noted.

The Orbiter tile damage site samples provided indication of Orbiter thermal protection system (TPS) materials, metallic particles, and embedded facility welding slag. The facility welding slag is believed to be post-landing incurred as no evidence of flight/heating effects (tile glazing) was present on the sample. The Mate-Demate Device (MDD) may be the source of this debris.

The SRB slag reference sample, intended to identify the embedded tile debris material, provided no similarity to the debris.

This mission's post landing tile inspection provided no evidence of an orbital debris impact.

11.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 9 Post Launch Anomalies were observed for STS-35. This list contains 3 IFA candidates.

11.1 LAUNCH PAD/FACILITY

1. Two cable tray covers were missing from the FSS 215/RSS 207 foot level. Other cable tray covers on the RSS 135 and 175 foot levels were loose. The modification program to replace old cable tray cover fasteners with new trapeze fasteners is still in work at Pad 39B. (KSC facilities item).

11.2 EXTERNAL TANK

1. Examination of ET post separation on-orbit photography revealed the presence of at least 12 TPS divots in the LH2 tank-to-intertank flange closeout +Z side and one divot on the upper LH2 tank acreage TPS. Six of the divots have a major dimension of 8-10 inches. (IFA candidate).

11.3 SOLID ROCKET BOOSTERS

1. Three NSI fragments fell from the HDP #1 DCS/aft skirt stud hole shortly after launch. Four ordnance fragments fell from HDP #2; one from HDP #5, and one from HDP #8. Post flight inspection of the SRB's revealed the DCS plungers in HDP #1, 3, 5, and 6 had not seated properly. Five of eight DCS's retained less than 90 percent (Program requirement) of HDP ordnance debris with an overall system retention percentage of 58 percent. (IFA candidate).

2. Holddown post shoe shim material debonded at liftoff on HDP #1, 2, 4, and 6. Shim material on HDP #5 was also debonded and partially (50 percent) missing from two of the sidewalls. Shim material should remain intact and bonded through launch. (SRB Project item).

3. Two pieces of Instafoam fell from the RH SRB aft skirt near the HDP #1/aft ring area and the HDP #3/aft ring area early in flight. Aft skirt Instafoam should remain intact through water impact. (SRB Project item).

4. RH and LH frustum MSA-2 was debonded over fasteners in 51 places. MSA-2 should not be debonded. (SRB Project item).

5. A 10"X2" portion of Epon shim material was missing from the HDP #4 foot prior to water impact. Shim material should remain attached to the aft skirt through water impact. (SRB Project item).

11.4 ORBITER

1. The plunger in the EO-3 (LO2) separation fitting debris container was obstructed by a booster cartridge and failed to seat properly. (IFA candidate).

2. SSME ignition vibration/acoustics caused the loss of small pieces of tile surface coating material from the top side of the elevons. (Orbiter Project item).

APPENDIX A.

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
JANUARY 9, 1991

SUBJECT: Orbiter Debris Samples From STS-35 Landing

LABORATORY REQUEST NO: MCB-0989-90

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 FOREWORD:

1.1 REQUESTER: R. F. Speece/TV-MSD-22/1-2946

1.2 REQUESTER'S SAMPLE DESCRIPTION: The samples were from OV-102, STS-35 Landing and were identified as:

A. Window samples
1. W#1.
2. W#2.
3. W#3.
4. W#4.
5. W#5.
6. W#6.
7. W#7.
8. W#8.

B. Residue in tile hit
9. Tile 191023-262
10. Tile 191037-097-008164
11. Tile 391011-398-009327

C. Wipes from LOX and LH2 ET umbilicals
12. LOX ET/ORB umbilical
13. LH2 ET/ORB umbilical

1.3 REQUESTED: Perform chemical identification analysis and compare to known STS materials.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

The samples were analyzed by means of optical microscopy (OM) and electron microprobe with energy dispersive spectrometry (EDS).

2.2 Results:

2.2.1 The particulates were classified into components on the basis of color and texture by OM. The classified components from window samples are listed in Table 1 with elemental analysis.

Table 1

Component ID	Elemental analysis by EDS*	
	Major	Minor
1.Metallics	Cu,Fe,Cr,Cd,Zn,	Ni,
2.Blk mtls	Fe,Cr,Cl,S,P,Si,Ca	K,Ti,Ni,Mg,Na,Al
3.Red mtls	Fe,Cr,Cl,Ca,Si	K,Al,Ni,Na,S
4.Amber flake	Fe,K,Si,Al	Ti,Mg
5.White mtls	Na,Cl,Si,Ti,Al,	K,Ca
6.Lgt green mtl	Si,Al,K,Zn,Cr,Ca	Fe,Cl,Mg
7.Yellow mtl	Ti,Cr,Si,Pb,	Fe,K,Ca,Al
8.Blk sphere	Fe	
9.Glass fibers	Si,Al	Ca
10.Lgt pink mtl	Ce,La	S,Cl,Ca
11.Organics	ND	

ND: Not Determined.
*: O, C, H, and B are not detectable by using this technique.

2.2.2 Table 2 lists estimated amounts of each component versus sample number.

Table 2

Sample No	1.	2.	3.	4.	5.	6.	7.	8.
1.Metallics	Fe	Fe	SS	x	Cd,Fe	Fe	Fe,Br	Br
2.Blk mtls	2	3	4	10	2	2	2	5
3.Red mtl	3	1	T	5	T	T	1	T
4.Amber flake	5	15	30	28	2	3	25	30
5.White mtls	60	61	26	5	40	85	15	10
6.Lgt green mtl	T	T	T	x	T	x	T	x
7.Yellow mtl	x	T	5	T	x	T	x	x
8.Blk sphere	T	T	x	T	x	x	x	x
9.Glass fibers	T	T	x	T	T	T	T	T
10.Lgt pink mtl	x	x	x	20	x	x	x	x
11.Organics	30	20	35	32	56	10	57	55
part size,um	1-350	1-300	1-400	1-350	1-200	1-200	1-250	1-300

Fe : Carbon steel. SS : Stainless steel. Br : Brass. T: Trace

2.2.3 The analytical results from samples 9 through 13 are listed in Table 3.

Component ID	Elemental analysis by EDS*		part size um
	Major	Minor	
B.Tile residue			
9.191023-262 tile			
a.Blk tile(70)	Si		1-2000
b.Wht fibrous tile(30)	Si		1-1500
10.191037-097 tile			
a.Red mtl(10)	Fe	Si,S,Cl,P,Ca,K	1-30
b.Blk tile(40)	Si		1-150
c.Wht fibrous tile(50)	Si		1-200
11.391011-398 tile			
a.Blk tile(40)	Si		1-110
b.Wht fibrous tile(60)	Si		1-100
12.Wipe,LOX			
a.Metallics(1)	Al,Fe,Cr	Ni	1-110
b.Blk mtls(5)	Si,Mg,Org	Fe,Al	1-2000
c.Brn mtl(55)	Cl,Si,Al	Ti,Cr,Fe,Ca,K	1-700
d.Wht mtl(15)	Si,Al,Mg	K,Cl,Ca,Zn	1-300
e.Glass fiber(8)	Si		10
f.Organics(16)	ND		1-900
13.Wipe,LH2			
a.Blk mtl(18)	Mg,Si,Al,P	Ca,K,Fe	1-700
b.Lgt brn mtl(35)	Si	Fe	1-500
c.Lgt grn mtl(T)	Fe,Cr,Ti,Ca,Si,Pb	Al,Mg	1-150
d.Glass fiber(2)	Si		10
e.Organics(55)	foam, others		L

(5): Estimated volume percent
T: Trace
ND: Not determined
* : O, C, H and B are not detectable by using this technique.

2.2.3 Figures 1 and 2 are low and high magnification SEM photomicrographs of black tile surface to show the fused or melted appearance.

3.0 CONCLUSIONS :

3.1 Window Samples

3.1.1 All samples except sample number 4 contained metallics. The metallics were composed of carbon steel, brass, Cd-metal, and stainless steel.

3.1.2 All samples contained black materials. The black materials were composed of corrosion products, Fe-Si rich materials, dust, and paint particles.

3.1.3 All samples contained trace to small amounts of red materials. The red materials were composed of rust, RTV, and some dust particles.

3.1.4 All samples contained amber flakes. The amber flakes were identified to be muscovite [KAl2(AlSi3O10)(OH)2].

3.1.5 All samples contained large amounts of white materials. The white materials were composed of salts (NaCl and KCl), Si-Al rich materials (probably high temperature insulation materials), paints, and Si-rich materials.

3.1.6 The samples 1, 2, 3, 5, and 7 contained trace amounts of light green materials. The light green materials were identified to be paints.

3.1.7 The samples 2, 3, 4, and 6 contained yellow paint chips. The samples 1, 2, and 4 contained trace amounts of carbon spheres.

3.1.8 All samples except sample 3 contained glass fibers. The glass fibers were composed of Si-Al rich high temperature insulation types.

3.1.9 The sample 4 contained light pink materials. The light pink materials were composed of Ce-La rich materials.

3.1.10 All samples contained large amounts of organics. The organics were not analyzed at this time.

3.1.11 The particle sizes were estimated to be in the range of 1 to 400 micrometers.

3.2 Tile Residue

3.2.1 The samples 9, 10, and 11 contained black dense tiles and white fibrous tiles. The sample 10 contained red rust particles in addition to above materials.

3.2.2 The black dense and fibrous tiles appeared to be from TPS and the surface of tile shows the fused or melted appearance.

3.3 Wipe from LOX and LH2

3.3.1 The wipes from LOX and LH2 contained metallics, black materials, brown materials, white materials, light green materials, glass fibers, and organics.

3.3.2 The metallics were composed of Al-particles and a 300 series stainless steel.

3.3.3 The black, brown, light brown, white, and light green materials appeared to be composed of a combination of dust, rust, paints, Si-rich materials, and Si-Al rich materials.

3.3.4 The glass fiber was identified to be Si-rich insulation type.

3.3.5 The organics were not analyzed at this time. However, The OM data suggested that the organics appeared to be composed of foam and other unidentified organics.

3.3.6 The particle sizes were estimated to be in the range of 1 to 2000 micrometer.

CHEMIST: H. S. Kim
H. S. Kim

APPROVED: J. F. Jones
J. F. Jones

MCB0989-90

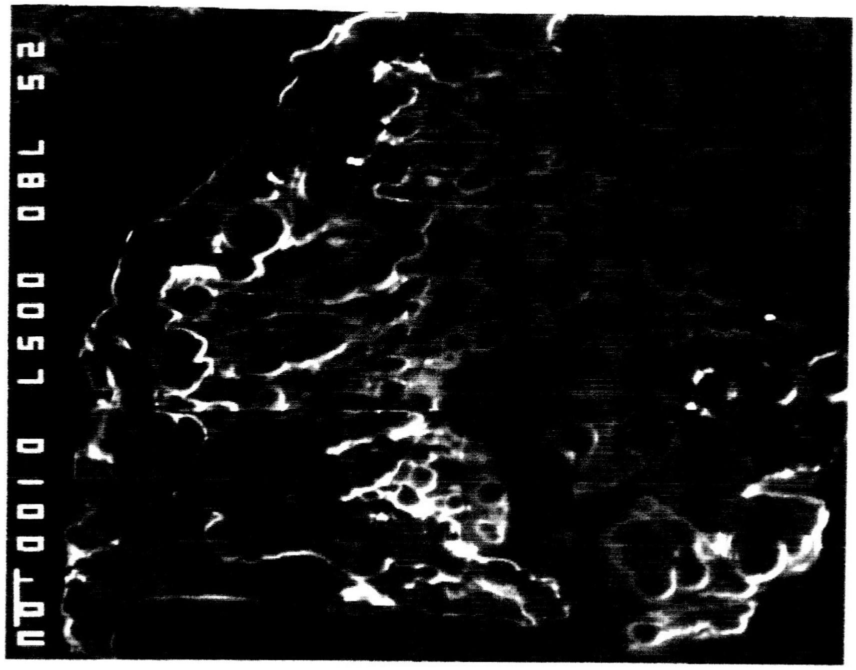


Figure 1. Low magnification SEM photomicrograph of fused or melted appearance of black tile. 78x.#9.

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BLACK AND WHITE PHOTOGRAPH

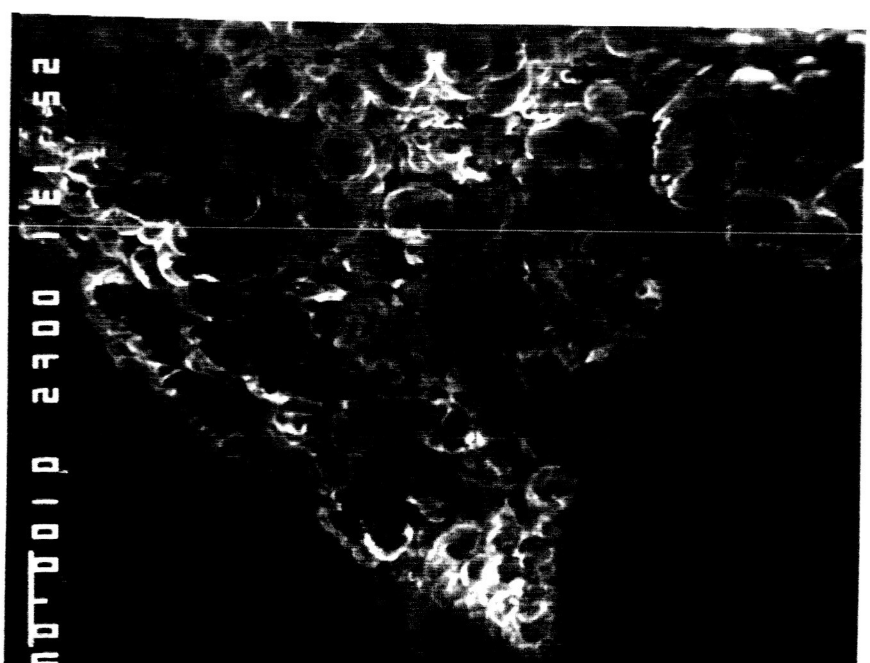

Figure 2. SEM photomicrograph of tile surface to show the spherical appearance of surface. 130x. #9.

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
FEBRUARY 5, 1991

SUBJECT: Orbiter Debris Samples From STS-35 Landing

LABORATORY REQUEST NO: MCB-0066-91

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 FOREWORD:

1.1 REQUESTER: R. F. Speece/TV-MSD-22/1-2946

1.2 REQUESTER'S SAMPLE DESCRIPTION: The samples were from OV-102, STS-35, and were identified as :

1. RH wing RCC #11 tee.
2. LH wing RCC #8.
3. Tile 191029-256.
4. Debris from tile 197007-146.
5. Reference sample SRB "slag."

1.3 REQUESTED: Perform chemical analysis and compare results to known STS materials.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

The samples were analyzed by means of Optical Microscopy (OM), X-Ray Diffraction (XRD) and electron microprobe with Energy Dispersive Spectrometry (EDS).

2.2 Results:

The particulates were classified into components on the basis of color and texture by OM and the analytical results are listed in Table 1.

Table 1

Component ID	Elemental Analysis By EDS*		Part Size um
	Major	Minor	
1.RCC #11(T)			
a.Blk mtls(20)	Si,Fe	Ti	1-40
b.Wht mtls(40)	Ti,Si	Al,Ca,	1-50
c.Organics(40)	ND		1-35
2.RCC #18(S)			
a.Metallics(T)	Cu,Zn,Fe		1-25
b.Red mtls(T)	Fe,Si		1-70
c.Blk mtls(60)	Si		1-70
d.Wht mtls(30)	Si,Al		1-30
e.Organics(10)	ND		1-30
3.Tile(S)			
a.Metallics(1)	Al		1-80
b.Blk dense tile(29)	Si		1-120
c.Wht fiber tile(70)	Si		1-1000
4.Debris			
a.Blk mtls(98)	Fe,Cu,Al,Si	Ti,Ca,Cl,S	
b.Red coats(2)	Fe	Si,P,S,Cl,Ti	
c.Red mtls(T)	Fe,Si		
5.Reference slag			
a.Blk Coats(1)	Si,Cl,Al	Mg,Na,S	
b.Wht mtls(99)	Al		

(5): Estimated Volume Percent.
S: Small Amount.
T: Trace Amount.
ND: Not Determined.
*: O, C, H, and B are not detectable by using this technique.

3.0 CONCLUSIONS:

3.1 The particulates from samples 1, 2, and 3 contained trace to small amounts of particles, and contained metallics, red materials, black materials, white materials, and organics.

3.2 The metallics from sample 2 were composed of brass and carbon steel, and the metallics from sample 3 were composed of Al-particles.

3.3 The red materials from sample 2 were composed of RTV.

3.4 The black materials from samples 1, 2, and 3 were composed mainly of black dense tile materials with trace amounts of rustic materials.

3.5 The white materials from sample 1 were composed of Si-rich materials and paint particles. The white materials from samples 2 and 3 were composed of Si-rich fibrous materials and Si-Al rich materials.

3.6 The organics were not analyzed at this time due to small amounts of sample.

3.7 The XRD data indicated that the black materials from sample 4 were identified to be a mixture of FeO (wuestite) and Fe_3O_4 (magnetite). The red materials were identified to be RTV.

3.8 The black coatings from sample 5 were composed of Si-Al-Cl rich materials, and the white materials were composed of alpha-corundum (alpha-Al_2O_3).

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APPROVED: J. F. Jones
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16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-35. Debris inspections of the flight elements and launch pad were performed before and after launch. Ice/frost conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and photographic analysis of Mission STS-35, and their overall effect on the Space Shuttle Program.

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